Vol. VIII. — No. 11. November 1926.


# BULLETIN

OF THE

# INTERNATIONAL RAILWAY CONGRESS

ASSOCIATION

(ENGLISH EDITION)


62. (01 (.493) & 625 .143.2 (.493) ]

## New test conditions in the Belgian State Railways' specification for rails, (1)


By JULES WILLEM,

INSPECTOR GENERAL OF THE BELGIAN STATE RAILWAYS,
CHAIRMAN OF THE PERMANENT WAY MATERIAL INSPECTION COMMITTEE,

and

JULES SERVAIS,

CHIEF OF METALLOGRAPHIC TESTS TO THE BELGIAN STATE RAILWAYS,
SECRETARY OF THE STORES AND INSPECTION COMMISSION OF THE PERMANENT WAY DEPARTMENT.


Figs. 1 to 67, pp. 935 to 978.

### INTRODUCTION.

We have prepared the following notes on the new conditions in the specification for rails for the benefit of all those whose duties bring them into touch with the question of rails from any point of view, either from the point of view of the inspection of material, or from the point of view of track maintenance. We have therefore not hesitated to mention the most elementary details in connection with their manufacture so as to better explain the various requirements of the specification.

These notes are followed by some examples of defects found in rails in service, and also some statistics of the number of broken rails for the year 1923.

In order to fully understand certain chapters of this article, we think that it is necessary to give a few details on the composition and duties of the « Permanent Way Material Inspection Committee », a body entrusted with all the questions of permanent way material, including rails.

The Committee, although attached to the Way and Works Department and in continual touch with the permanent way ordering office is, however, quite independent of the other sections of the Way and Works Department.

It consists of a chairman having at

(1) Translated from the French. This article was written more than a year ago, and has been held back in view of the number of articles which had to be published in connection with the tenth session of the Railway Congress held in London 1925. Since then, it has been completed by some recent additions. (*Note of the Editor.*)

least the rank of chief engineer, two vice-presidents and members appointed as secretaries or assistant secretaries chosen from the engineers, technical inspectors or section chiefs. One of these members, is in charge of the macrographic and micrographic tests.

A staff of inspectors, recruited from fitters and mechanics, having a certain number of years practical experience, work directly under the orders of the members of the Committee.

These men, who are distributed throughout the industrial centres of the country, follow the manufacture of the material in the works, carry out certain preliminary tests and prepare for the material to be passed.

As regards rails, these various operations are explained in the article which follows.

Rails are passed at the maker's works as soon as possible after the manufacturer has notified that the material is ready for passing and when the inspectors have completed the work of classification and the required preliminary tests.

Immediately the material has been passed, instructions are sent to the manufacturer to deliver the rails to the place where they are required if possible, or to the workshops where points and crossings are made in the case of rails intended for this purpose, and for the remainder to be sent to the distributing stores.

* * *

After quoting the technical requirements laid down in the specification, we will discuss the various clauses successively, as far as possible in the order in which they occur.

* * *

**RECEIPT OF MATERIAL.**

The contractor should inform the inspection Committee, at least eight days in advance of the date on which he intends to commence the manufacture of the rails.

The committee will keep in touch with the manufacturer and will proceed during manufacture to make the preliminary tests.

All the necessary tests are to be carried out at the maker's works, the cost being borne by the maker and the apparatus provided by him.

The apparatus should, before being used, be checked for accuracy by the Test Department at Malines. This verification shall be carried out whenever the Committee consider that it is necessary, and in any case whenever the period during which rails are being passed exceeds two years from the date when the first rails were passed.

The certificates should be addressed to the Chairman of the Permanent Way Material Inspection Committee.

The tensile testing machines should automatically indicate the apparent elastic limit of the test pieces used.

The arrangement of the falling weight test shall be as follows :

The two supports should be of cast iron resting on a base weighing at least 10 000 kgr. (22 000 lb.) placed on a masonry foundation at least 1 m. (3 ft. 3 3/8 in.) thick supported by solid subsoil.

No apparent movement must take place as the result of the falling weight.

The shape of the falling weight and of the rail supports must correspond as near as possible to the arrangement shown on the general drawing of the gauges and test pieces. The falling weight should be provided with an automatic release giving different heights of drop.

The manufacturers shall, at the commencement of rolling, submit, for the examination of the Committee, a speci-

men of the rails which they are to produce. This specimen, which shall be perfectly true to dimensions, will remain the property of the Administration, and shall bear the marks of the rolling mill specified in the chapter on « Special conditions of manufacture ». It shall serve as a sample, both as regards the profile and the marks, and shall be stamped both by the maker and by the Administration.

Independently of the tests carried out at the maker's works, the Administration reserves the right to carry out analyses or other tests in its own laboratories so as to ensure that the rails produced comply satisfactorily with the conditions laid down in the specification.

The manufacturer shall not be asked to be present at these tests. However, if the results obtained are not satisfactory or do not agree with those obtained in the maker's works, the manufacturer shall be informed, and before proceeding, if necessary, to reject the rails, the manufacturer shall be allowed to put before the Committee, within eight days of the notification, a demand for an additional test at which he may be present or represented.

The selection of the test pieces shall always be carried out by the Committee.

The various test pieces are to be prepared by and at the cost of the manufacturer in order to be forwarded to the Test Department at Malines, and should be made in accordance with the dimensions shown on the general drawing of gauges and test pieces.

The manufacturer must provide free of charge packing cases and other material necessary for packing the test pieces or ends of rails which are to be sent away for these tests.

The cost of the work carried out in Malines to finish or modify the test pieces which the manufacturers have not made themselves shall be borne by the manufacturers. The same applies to the cost of the tests and of the carriage or analysis of test pieces or samples which are not passed as satisfactory by the Committee.

If more than two weeks elapse between the date of the arrival at Malines of material or samples to be tested or analysed, and the date on which the result of the test or analysis is notified to the manufacturer, the latter shall be entitled to extend the delivery period by the additional number of days which have elapsed, provided that the delay is one for which the Administration is responsible. Not more than 1 000 tons shall be delivered as the result of one series of tests.

The rails on delivery should be stacked in the storage park.

The rails are to be classified according to length, laid head upmost and arranged in a stack of such a height that all the rails may be examined without any undue handling.

The manufacturer is not allowed to deliver rails from casts other than those which have been passed during their manufacture.

It is also forbidden to deliver again rails which have been subjected to tests.

The foregoing merely lays down the general conditions in connection with the tests of the method of preparing for the same.

It is the practice of our Administration to abstain from entering into questions of manufacture, leaving the choice of the processes, which are considered to give the best results as shown by the tests, to the judgment of the steel makers, who are specialists in this matter.

Material is therefore accepted solely *on the quality of the finished article* as shown by the tests.

However, the specification stipulates that the Inspection Committee may keep in touch with the process of manufacture, but this supervision at the works is less with a view to controlling the processes than to ensure a regular output in all

the stages of the handling of material from the steel works up to the storage park.

The presence of a representative at the works throughout the whole of the process of manufacture is justified by the fact that it is necessary for the Committee to be informed of any incidents which may occur during the process of manufacture, so that they may investigate whether any unusual incidents which may occur during manufacture have affected the quality of the rails. They may thus judge whether special attention is to be given to any particular tests, and where necessary, carry out supplementary tests on material from certain cast numbers.

As example of the information which should be in the possession of the Committee because of the possibility of their exerting an influence on the quality of the finished product, the following may be quoted :

1. Lack of co-ordination which may at certain times occur between the various sections of the steel works, from accidents or breakdowns to convertors, furnaces or rolling mills or from any unusual occurrence;

2. Resumption of rolling rails to soon after the interruption of a regular process, for example, after Sundays, holidays, closing of works, strikes, etc.;

3. The use of metal from the bottom of the ladle for the last ingot.

### Testing machines

The Administration has always adhered to the practice of carrying out the tests at the maker's works by means of testing machines supplied by the manufacturers, provided that these testing machines are first checked and approved by the Test Department at Malines as regards the correctness of their readings and their being in satisfactory working order. Unfortunately there are at the various steel-works many different types of testing machines, and the Administration may not urge to have these standardised. A great number of these are types which give very valuable information.

For this reason, in order that the results may be received with confidence, the testing machines are checked whenever the Committee considers it necessary, and in any case within a period of two years.

It is important to ensure that the tests are carried out under comparable conditions, and in such a way that the information required in the specifications may be easily extracted.

For this reason some of the older types of tensile testing machines have been rejected, and the same reasons have led the Committee to stipulate certain conditions for all machines, for example, the automatic release for all the falling weight machines and that the falling weights should be similar in design.

### Preparing test pieces

It is perhaps worth while to lay stress on the importance attached to the preparation of the test pieces, because any error in their preparation may entail additional checks being made, or may even lead to a considerable amount of material being rejected.

As regards the tensile test pieces, it is important to ensure that the turned test pieces are not bent during their preparation, and it must also be borne in mind that any rough mechanical treatment of these tensile test pieces may result in reducing their tensile strength and elongation.

The test pieces should be left for two

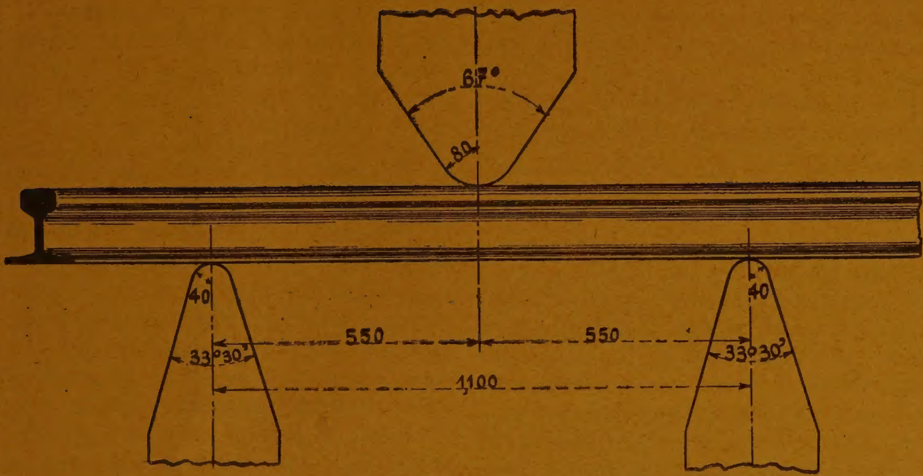



Fig. 1. – Arrangement of supports and falling weight.

or three days and their surfaces should be as highly polished as possible so as to remove any causes which may exert an unfavourable influence on their resistance to fatigue.

On the subject of « the influence of tool marks or other defects in the finish on the resistance of steel to fatigue », Mr. Norman Thomas has carried out a series of experiments at Oxford University, and he summarises the results obtained in the attached table.

| FINISH. | Maximum reduction per cent. in the resistance to fatigue. |
|---|---|
| Turned finish | 12 |
| Rough file | 18 to 20 |
| Bastard file | 14 |
| Smooth file | 7.5 |
| Rough emery cloth No. 3 | 6 |
| Emery cloth No. 1 | 4 |
| Fine emery cloth (No. 0 or FF) | 2 to 3 |
| Fine carborundum | 2 to 3 |
| Fine grinding wheel | 4 |
| Accidental scratches (maximum) | 16 |

Certain details in the method of carrying out the tests may also have an adverse influence.

*Tensile tests.* — Once the test piece is fixed in the machine, it is necessary to ensure that the tensile force is exerted along the longitudinal axis of the test piece.

The rate at which the force is applied should be regular and not vary during the test.

The pipes to the cylinders in hydraulic testing machines should in no case be connected to another hydraulic machine, even if an accumulator is provided, in order to avert the possibility of prematurely fatiguing the test piece by an alternating load.

On the other hand, there are in some cases local defects such as cracks, non-metallic enclosures, etc., in the broken portion, to which the fracture may be attributed.

Additional tests may satisfy the inspector as to the real quality of the metal, but who can say that certain casts have

not been rejected in consequence of fractures due to local defects which have not been noticed?

It is therefore necessary to carefully examine the test pieces both before and after testing.

*Falling weight test.* — It is of the utmost importance to ensure before dropping the weight that the lengths of rails rest properly on the two supports, otherwise the sides of the foot of the rail which receive the blow may be broken at the supports.

It goes without saying that the supports should be parallel and level so as to avoid any asymmetrical forces being exerted on the rail.

*Notched bar tests.* — In the test in the Charpy machine, the test pieces should be finished to the correct dimensions and the bottom of the notch should be as highly polished as possible. Consistency of the results depends very largely on the care taken in preparing the test pieces.

Another equally important point is to arrange the notch in the test piece in such a way that the test is carried out in the direction of rolling as shown on the drawing.

A notch cut in the other direction would have the effect of testing the metal in a transverse direction and would therefore falsify the results.

It is important therefore to carefully mark the side on which the notch is to be cut.

### Acceptance of rails.

The acceptance or rejection of a batch of rails is decided upon by the Permanent Way Material Inspection Committee at the maker's works.

Experience has shown that it is not desirable to allow more than 1 000 tons to be passed in one batch if it is desired to carry out all the stipulated tests methodically and to assist the makers in turning out a satisfactory output.

The method of passing the material is as follows :

The rails, when finished, after having been thoroughly examined by special employees of the makers, are classified according to length, and are then presented one by one for examination by one of our test inspectors. The latter satisfies himself that the section, finish, length, position of the bolt holes are correct, and that there are no fins left by the rolls.

Any rails which are considered unsatisfactory are put aside, while those which are suitable for acceptance are spread out as laid down in the specification.

The condition that rails are not to be presented for inspection in a stack, but that they must be spread out is a serious matter for the makers. The Belgian steel makers for the most part lack the necessary space, and therefore are hardly able to fully carry out this condition. It should be so arranged, however — and the inspector should insist upon it — that all the rails are to be accessible.

If, therefore, the whole consignment cannot be spread out, it is essential that the stack should not be a high one, and that lifting appliances should be provided so that the rails may easily be moved and thus lay open to view successively each layer in the stack.

When the rails are to be finally passed, the members of the Committee carry out all the mechanical and macrographic tests, and a further inspection of each individual rail.

When the rails have been passed, they

are stamped at both ends with the distinguishing mark of the Committee.

* * *

### GAUGES.

The makers shall be obliged to submit to the Committee two of each of the gauges shown on the general drawing of gauges and test pieces. These shall be passed as satisfactory before being used by the Committee.

After being checked, the two sets of gauges shall be stamped by the Committee. One set will be sent back to the makers, and the other set shall be retained for use by the officials and agents of the Committee.

We have not thought it advisable in this article to reproduce in its entirety the general drawing of the gauges, prefering to deal hereafter with each one separately.

* * *

### SPECIAL CONDITIONS OF MANUFACTURE.

#### Composition of the metal.

The rails shall be of hard steel with a minimum silicon content of 0.12 %.

The makers shall be obliged to furnish the Committee with a complete chemical analysis of all the casts presented for inspection. These analyses shall give the percentage of silicon, manganese, carbon, sulphur and phosphorus.

Before the war, the specifications for rails did not contain any conditions as regards the chemical composition of the metal. At the present time, a minimum silicon content is required, and the maker has to furnish a complete analysis of all the casts.

As a check, the test department laboratory at Malines carries out an analysis of a certain number of casts as selected by the Committee.

In order to obtain comparable results and to avoid discussions between the laboratories, it may appear necessary to state in the specification the analytical processes to be used in determining each of the constituents, but this would entail modifications in the specification every time chemical progress discovered a new method of analysis. It is better to rely on mutual arrangements between the laboratories before making the analyses, or where there is any discrepancy, to make use of the more perfect process [1].

---

[1] At the Malines laboratory the proportion of silicon is determined by weight. Drillings are taken from the head, web and foot of the rail, and after sampling, the silicon is estimated in the form of an insoluble silicate.

The process is as follows :

Oxidise the silicon so as to transform it to silica, which is rendered insoluble by heating, it is then collected, freed from fixed salts with which it is accompanied by washing, dried, calcined and weighed :

$$Si\,O_2 \times 0.4702 = Si.$$

The conditions upon which accuracy depends are as follows :

1. To totally oxidise the silicon;
2. To render perfectly insoluble the $Si\,O_2$;
3. To completely remove from the silica all the salts or other fixed components.

*Method used.*

Take 5 grams (2.82 drams) of steel. Dissolve in a porcelain beaker with 80 $cm^3$ (4.882 cubic inches) of hydrochloric acid diluted with an equal quantity of distilled water. Evaporate on a sand bath and add 20 to 30 $cm^3$ (1.220 to 1.830 cubic inches) of hydrochloric acid, then add 200 to 300 $cm^3$ (12.200 to 18.300 cubic inches) of boiling water. After dissolving the iron salts, filter on an ashless filter paper; wash with boiling water containing 5 °/₀ of hydrochloric acid, dry, calcine and weigh.

If the steel contains small quantities of oxide, these will not be attacked. As these are heavy, when the silica has filtered, they may be separated by decantation and dissolved in strong hydrochloric acid.

The question of silicon has been dealt with by one of the authors in the first part of this article (1).

Up to October 1924, the minimum silicon content required in the specifications was 0.20 %, but actually attained 0.23 to 0.30 %. The presence of this element in these proportions gave rise to certain difficulties in rolling and led, according to the steel makers, to the production of dangerous lines, cracks and exfoliations. This opinion has been expressed too recently to have been confirmed in practice.

This consideration has led the Belgian State Railways to reduce the minimum silicon content to 0.12 %.

In practice, moreover, the amount will be greater than 0.12 %, as the steel makers always take care not to be below the minimum quantity stipulated.

As regards the other components, their limiting percentages are not fixed, but the complete analysis gives an indication of the quality of the steel presented for test, and an examination of these analyses is of very great importance in guiding the Committee in deciding from which casts the test pieces are to be taken for the final acceptance, for it is out of the question to carry out complete tests on the 100 casts included in a batch of rails, and it is necessary to be content with taking from 20 to 30 of these casts. Partial tests may be carried out on a certain number of the remaining casts (2).

As an example, we give in the appendix the results of analyses such as are taken, this being the complete account of the examination of a batch of rails which was offered for inspection in 1924.

*Ingots.*

The ingots shall be at least sufficiently large for two rails of the ordinary length of 18 m. (59 feet).

The ingots shall not be laid on their side before solidification is complete.

After blooming, ingots shall have sufficient cut from the head to remove from the metal used for the rail all traces of piping, blow holes, or segregation.

In order to render clearer the explanations which follow, we may here refer to what occurs during the solidification of the steel and rolling.

The steel gives rise, during solidification, to physical and chemical phenomena, which have the effect of rendering the metal heterogeneous as a result of contractions and separations which occur during cooling.

The contraction, which is a physical phenomenon, gives rise to *piping*, while the formation of a solid solution, which is a chemical phenomenon, leads to *segregation*.

During the gradual cooling which commences at the surface of the ingot in contact with the walls of the ingot mould, the metal passes by successive layers from the liquid state to the solid state, and in so doing suffers a contraction of its volume which leads finally to a cavity in the upper central portion which solidifies last.

This contraction frequently causes a cavity of funnel shape, known as « piping ». Around this piping are collected various impurities consisting of compounds of carbon, manganese, sulphur, phosphorus and non-metallic enclosures consisting of fragments of the lining of the furnace.

(1) See « Some considerations on the position of the question of steel rails in Belgium » by J. Servais, in the *Railway Congress Bulletin*, July-October 1925 number.

(2) It should be noted that the steel works usually carry out, before offering the material for inspection, for their own information, tensile or impact tests on all the casts, or at any rate on some of them.

These impurities, which as a whole are known by the general term of « segregations », have the effect of lowering the solidifying point of this part of the head of the ingot, which remains liquid, thus accounting for their accumulation in this zone of retarded solidification.

It is therefore necessary to distinguish between *piping* and *segregation*. On the other hand, the temperature, the nature of the metal, its viscosity, the form of the ingot mould and the thickness of the walls and the time taken in pouring are factors which have an effect, to a greater or less degree, on the local chemical composition and on the structure, and have an effect on the liberation of gas occluded in the metal. This gas arises from three sources :

1) The absorption of hydrogen and nitrogen as dissolved gas in the liquid metal;

2) Trapping of air at the moment of pouring;

3) Chemical reactions which occur during and after solidification.

Where the gas remains imprisoned in the interior of the ingot, this produces a number of small holes, known as « *blow holes* » breaking the continuity in the mass of the ingot.

At the same time, there are produced internal *cracks* resulting from the more or less regular conditions under which contraction takes place.

On the faces of the ingots are also surface cracks characterised by a number of superficial defects which may arise from local occlusions.

Unless special precautions are taken to minimise the various defects which we have just mentioned to the absolute minimum, the steel will be unsuitable for its required purpose. Therefore, recourse must be made to various chemical or mechanical methods which have the object of improving the ingots. These measures tend to the localisation of the piping, the elimination of the gas, and finally the removal of the unsound portions of the ingot after blooming by cutting off the portion containing the piping and segregations. We cannot enter here into other details without going beyond the scope of this article.

Before rolling, the ingots which have been removed from the ingot moulds are placed in pits to regularise their temperature during the completion of solidification.

It goes without saying that the time which they remain in the furnace and the temperature of the furnace has a considerable influence on the crystalisation of the metal and consequently on the quality of the product.

If kept too long at a high temperature, it will have the effect of producing a coarse crystaline structure, which will render the steel brittle on account of liability to intercrystaline rupture.

An insufficient time, on the other hand, will allow the metal to remain in distinct isochemical or isothermal layers which will lead to a lack of homogenity in the metal.

If the ingot is taken for blooming before it has remained sufficiently long in the soaking pits, the central portion will be still liquid and will be forced out under the pressure exerted by the rolls. It is then said that the ingot is too « young ».

If the liquid metal is not forced out as the result of the solidification of the head of the ingot, it may form zones of different carbon contents arising from the successive solidifications.

Macrographs, which will be dealt with later, form an effective means of ascer-

taining the constitution of the ingot or of the rail after rolling.

* * *

The clause dealing with the size of the ingots has the object of preventing the maker from using too small ingots which would increase the number of rails made from the head and would therefore increase the risk of segregation in the rails without producing any improvement in the structure.

The weight of the ingots used by our steel works range as a rule from 3 000 to 4 500 kgr. (6 600 to 9 900 lb.).

* * *

After taking from the pits, the completely solidified ingots are taken for blooming, and after cogging and rough rolling to a sufficiently reduced section, the head and the base of the ingot is cut off.

*Generally speaking, it can be said that the quality of the rails very largely depend on the trouble taken to remove unsound portions of the ingot.* We will enter into details later. As regards cutting off the base of the ingot, this is done to remove impurities which may have collected during solidification.

The clause which forbids the ingots to be laid on their side before solidification is complete, is with the object of preventing the displacement of the liquid portion in the head of the ingot before solidification in order that the piping and segregation shall not be displaced towards the centre of the ingot. Any doubt as to the position of this portion would render the ingot unfit for use, or at any rate would render it useless to cut off certain portions of the ingot.

The ingot retains all the original defects due to piping, and the walls of the internal cavity are brought together by rolling without welding and separate when the pressure of the rolls has been removed. To this may be attributed the cases where the head of the rails in service have become detached over several metres length, as is sometimes found in the metal of the rail.

*Rolling.* — After cogging, the bloom, reduced to a suitable section and with the unsound portions cut away, is passed on to the roughing rolls, intermediate rolls and finishing rolls, which are formed with grooves designed so as to distribute the metal in a regular manner in order to arrive progressively at the final section of the rail.

Without entering into the details of manufacture, we may say that the design of the rolls, based on the correct application of the laws of cohesion, constitute the most important part of the technique of rolling.

The design of the rolls is still at the present day looked upon as a specialised subject, the principles of which have for a long time been empirical, and have only been dealt with by specialists in this branch.

Geuze has laid down the law of the flow of metal as follows :

In order that any section may be easily rolled, it is necessary that at each time of passing through the rolls all the portions of the same section may elongate by an equal amount, extend the same distance in the same time, as would be the case if the metal were liquid, and forced to flow through an orifice having the same shape as the space between the rolls under the influence of a uniform pressure acting over the whole of the section.

After rolling, the rails have again a portion cut from the end sufficient to

ensure that they are entirely free from segregation. The portions cut from the head of the rail are submitted to the preliminary impact tests with a 4 m. (13 ft. 1 1/2 in.) drop.

We might add that the *total amount* of metal cut off, both on the bloom and on the rail after rolling, is as a rule from 20 to 25 % of the weight of the ingot, if one wishes to entirely remove all traces of piping and segregation.

We give later, as a typical example, a drawing of the rolls for 52 kgr. (104 lb. per lineal yard) Goliath Vignoles rails, and a table of the dimensions of the successive grooves which we take from Mr. L. Geuze's treatise on « Forging and rolling », page 188.

| Number of groove. | Width of groove, in millimetres (in inches). | Thickness of the web, in millimetres (in inches). | Thickness of the foot | | Thickness of the head | |
|---|---|---|---|---|---|---|
| | | | at the edge, in millimetres (in inches). | at the web, in millimetres (in inches). | at the outside, in millimetres (in inches). | at the web, in millimetres (in inches). |
| 7 | 147 (5.787) | 17 (0.669) | 10 (0.394) | 21 (0.827) | 36.5 (1.437) | 47.5 (1.870) |
| 6 | 145.5 (5.729) | 17.75 (0.699) | 10.5 (0.414) | 22 (0.866) | 38 (1.496) | 49.25 (1.939) |
| 5 | 144.5 (5.689) | 19.5 (0.768) | 11.4 (0.449) | 24 (0.945) | 41.25 (1.624) | 53.5 (2.107) |
| 4 | 143.5 (5.650) | 22.5 (0.886) | 12.75 (0.502) | 26.75 (1.054) | 46.75 (1.841) | 60.5 (2.382) |
| 3 | 142 (5.591) | 26.75 (1.054) | 14 (0.551) | 30 (1.181) | 54.5 (2.146) | 70 (2.756) |
| 2 | 140.5 (5.532) | 33.5 (1.319) | 16.5 (0.650) | 34.5 (1.359) | 65.5 (2.579) | 82.75 (3.258) |
| 1 | 139 (5.472) | 43.5 (1.713) | 18.5 (0.729) | 39 (1.535) | 73.5 (2.894) | 96 (3.780) |
| P[2] | head of rail. | 137 (5.394) | 20 (0.787) | 30 (1.181) | ... | ... |
| P[1] | 165 (6.496) | 146 (5.748) | 34 (1.339) | 45 (1.772) | ... | ... |

### Section of rails.

The rails should be correct to the section shown on the general drawing of gauges and test pieces. They must be within the following limits :

± 0 mm. 5 (0.0197 inch) for the height of the section, width of the head and thickness of the web;

± 1 mm. (0.039 inch) for the width of the foot;

\+ 0 mm. 25 to — 0 mm. 75 (+ 0.0098 to — 0.029 inch) for the fish plate bolt holes;

no tolerance being allowed on the inclined surfaces against which the fish plates bear.

The section of the rails should be strictly uniform throughout their length, and especially at the ends which are to be held by the fish plates. Care must be taken not to alter the section by cutting. The various radii must conform strictly to the dimensions given on the drawing.

Before the introduction of the new specifications, rails were checked merely on the nominal profile by means of ordinary gauges (see figures 5 and 6). Variations in the dimensions, either above or below the figure shown on the drawing, were measured by feelers or depth gauges.

This method caused considerable delay in passing the rails. No official tolerance was fixed, discussions took place between the makers and the inspectors as regards the limits which could be allow-

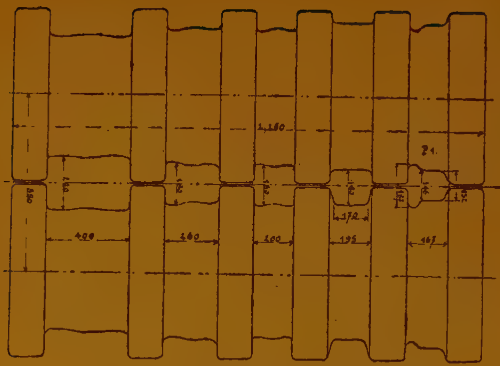


Fig. 2. — Roughing rolls 850 mm. (2 ft. 9 15/32 in.) centre to centre.

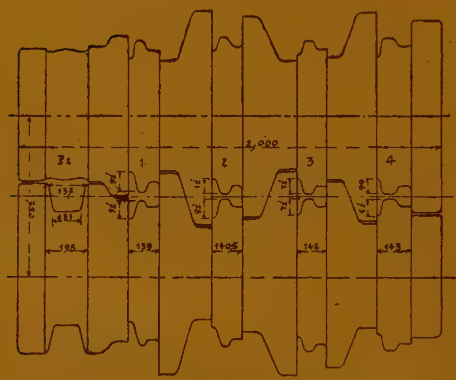


Fig. 3. — Intermediate rolls 750 mm. (2 ft. 5 1/2 in.) centre to centre.

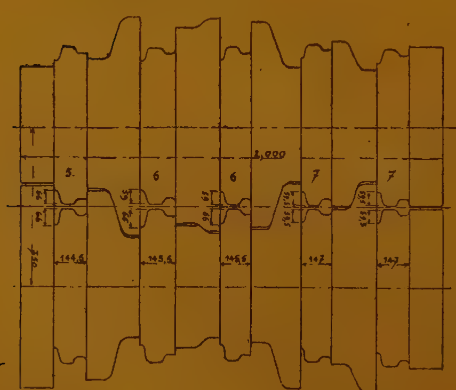


Fig. 4. — Finishing rolls 750 mm. (2 ft. 5 1/2 in.) centre to centre.

Figs. 2 to 4.

ed, each party defending his own particular point of view, and the result was that the rails supplied were not entirely uniform.

In this way rails were accepted which had errors in the section or fish-plate bolt holes which were too large. The manufacture of points and crossings, in which the amount to be planed away is dependent on the theoretical section of the rails, was very much impeded, and the fastenings, which took a bearing on the inclined fishing surfaces, were subject to play which gave serious trouble to the makers and caused rapid deterioration of the points and the crossings in service.

At the present time, any discussion is impossible in view of the adoption of minimum and maximum dimensions to which, if the rails do not conform, they are not accepted.

Incidentally, we may mention that the system of inspection by limit gauges has been applied by the Committee since 1919 for the verification of the majority of material submitted to it.

The determination of the suitable tolerances was not an easy task. If on the one hand data as regards the figures quoted in the specifications of important foreign railways was a source of valuable information, the great differences between the tolerances allowed in these various specifications for the same dimension rendered this somewhat confusing.

It was necessary to obtain rails which were as uniform as possible, that is to say, the tolerances should be as fine as possible, at the same time keeping them within what could be commercially produced so as not to render production almost impossible or even very difficult.

The limits proposed by the railway administration were decided upon after

consultation with the principal Belgian steel works supplying the rails.

Therefore we can say that since the application of the new specification we have met with no criticism on the part of the steel makers, who declare, however, that our conditions are as strict as can be reasonably demanded from commercial methods of manufacture and rolling.

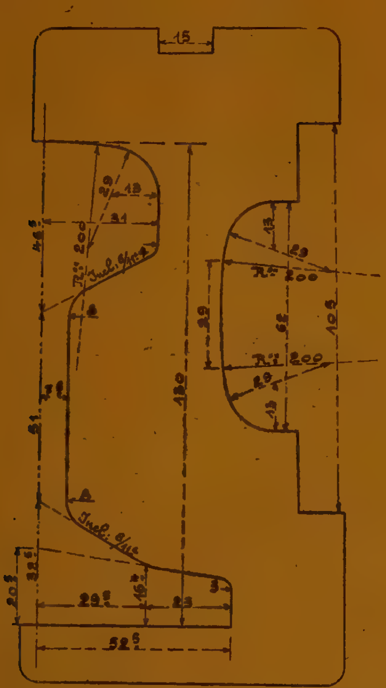


Fig. 5. — For rails 40.650 kgr. per metre (81.94 lb. per yard).

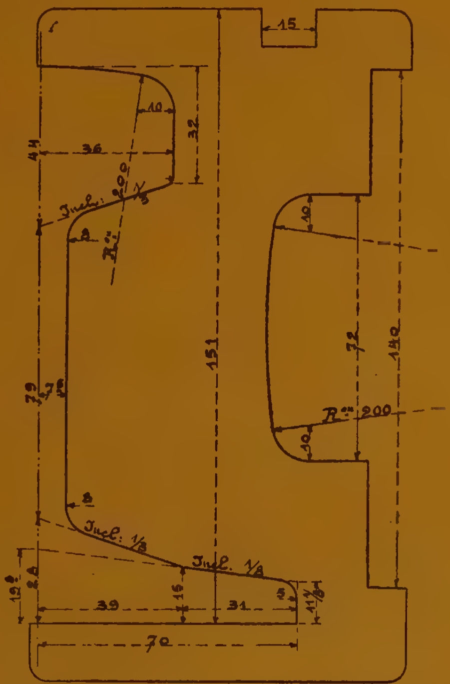


Fig. 6. — For rails 50 kgr. per metre (100.79 lb. per yard).

Figs. 5 and 6. — Old type gauges.

*In general, one may say that if the makers naturally oppose an increase in the accuracy of the methods of checking the products of their manufacture, the net result is that each justifiable increase in the strictness of the tests rapidly brings about improvements in the method of manufacture which are advantageous both to the producer and consumer.*

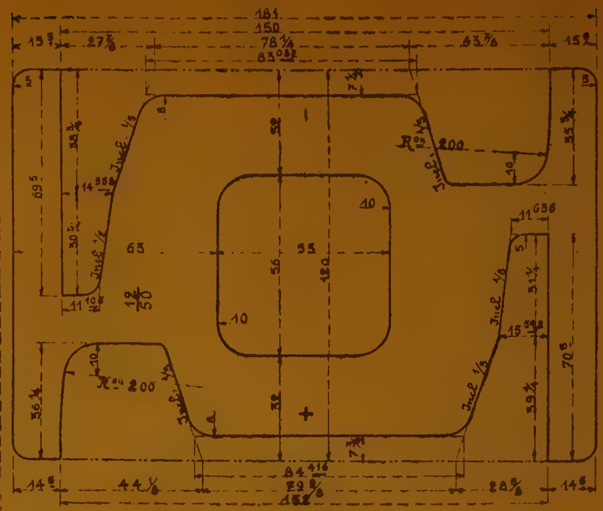
We give a reproduction of the general drawing of gauges and test pieces separately, so that under each heading we can deal with the corresponding gauges. (See figures 7 to 22, 28 to 31, 50 and 51.)

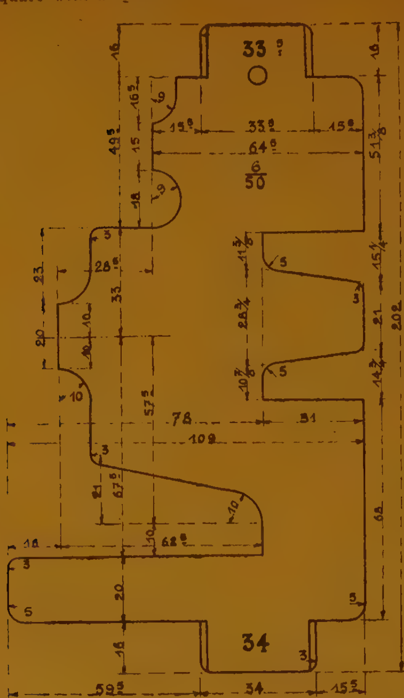
### Length of rails and drilling of bolt holes.

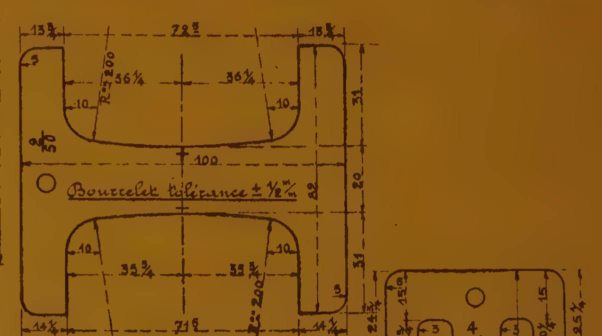
Rails required for open line are of the ordinary length of 18 m. (59 ft. 5/8 in.), both for the 40.650 kgr. (81.94 lb. per yard) rails and the 50 kgr. (100.79 lb. per yard) rails.

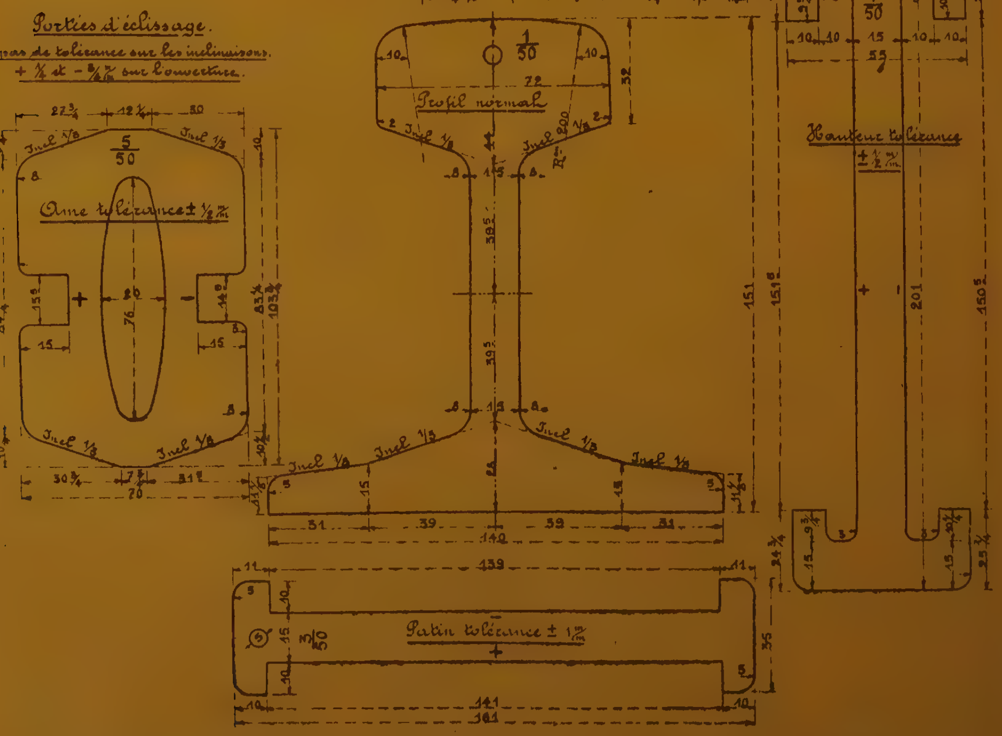
Female gauge with minimum and maximum tolerances.

Inclination of foot furthest from web: tolerance ± 1/4 mm. (0.0098 inch). Bolt holes: tolerance ± 1/2 mm. (0.0196 inch) on diameter and vertical position. For checking that web and head are square with the foot.





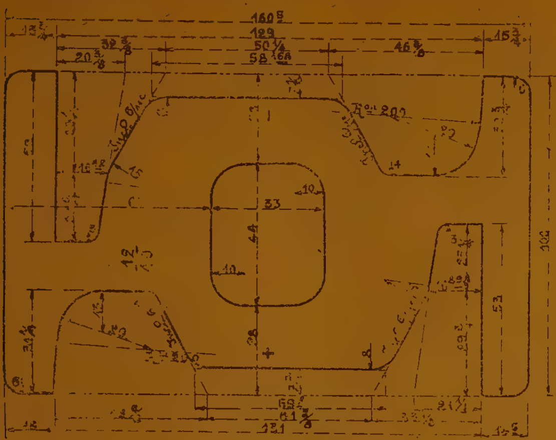


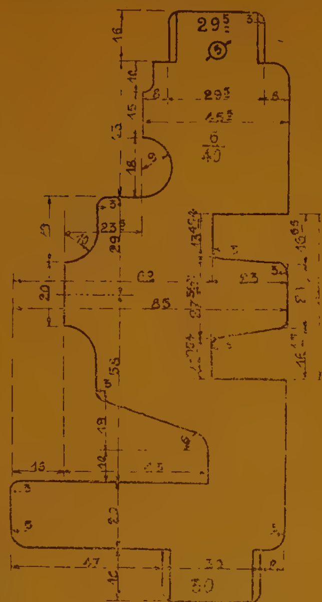

Figs. 7 to 13. — For rails 50 kgr. per metre (100.79 lb. per yard).

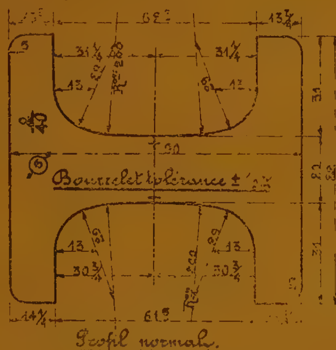
*For explanation of French terms, see opposite page.*

Female gauge with minimum and maximum tolerances.



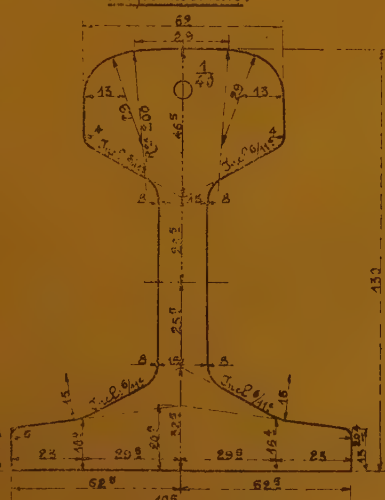
Inclination of foot furthest from web, tolerance ± 1/4 mm. (0.0098 inch).
Bolt holes: tolerance ± 1/2 mm. (0.0196 inch) on diameter and vertical position.
For checking that web and head are square with the foot.

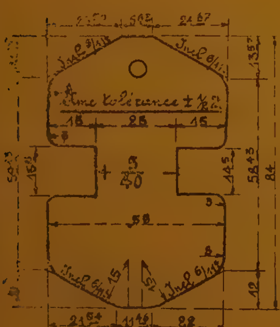


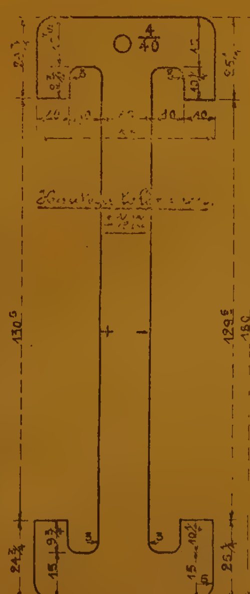


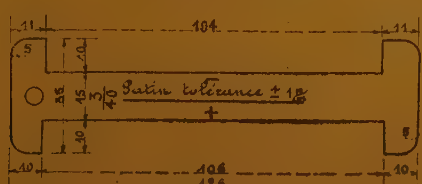

*Explanation of French terms:*

Bourrelet tolérance ± 1/2 mm. = Head of rail tolerance ± 0.0196 inch. — Portées d'éclissage, pas de tolérance sur les inclinaisons, + 1/4 et — 3/4 mm. sur l'ouverture = Fish plate bearing surfaces, no tolerance on the inclinations, + 0.0098 and — 0.029 inch on distance between surfaces. — Ame, tolérance ± 1/2 mm. = Tolerance on web ± 0.0196 inch. — Profil normal = Normal profile. — Hauteur tolérance ± 1/2 mm. = Height tolerance ± 0.0196 inch. — Patin tolérance ± 1 mm. = Width of foot tolerance ± 0.039 inch.




Figs. 14 to 20. — For rails 40.650 kgr. per metre (81.94 lb. per yard).

The administration reserves the right to include in the rails supplied :

1. A quantity of 17 m. 88 (58 ft. 7 15/16 in.) rails which may be one fifteenth of the total tonnage;

2. A quantity of one tenth of the total tonnage of various short rails less than 17 m. 88, some of which are used for the manufacture of points and crossings and some for open line.

At least one twentieth of this partial quantity shall be composed of rails 12 m. (39 ft. 4 1/2 in.) long;

3. A quantity equal to 1 % as a maximum of the rails for open line in lengths varying from 18 to 28 m. (59 ft. 5/8 in. to 91 ft. 10 3/8 in.).

The following tolerances are allowed in the length of rails :

± 1 mm. (3/64 inch) up to 6 m. (19 ft. 8 1/4 in.);
± 1 mm. 5 (1/16 inch) up to 12 m. (39 ft. 4 1/2 in.);
± 2 mm. (5/64 inch) up to 18 m. (59 ft. 5/8 in.);
± 3 mm. (1/8 inch) above 18 m. (59 ft. 5/8 in.).

Each end of the 40.650 kgr. rails shall be drilled with *three* fish plate bolt holes in the web. Moreover, all the 17 m. 88 and 18 m. rails shall be drilled with *four* additional bolt holes and 12 m. rails with *two* additional bolt holes for fixing the ends of the fish plates.

Each end of the 50 kgr. rails shall be drilled in the web with *two* holes for fish plate bolts. Moreover, all the 17 m. 88 and 18 m. rails shall be drilled with *four* additional holes and the 12 m. rails with *two* additional holes for fastening stop plates.

The position of the holes is given on the drawings; their dimensions are as follows :

30 mm. (1 3/16 inch) diameter for fish plate bolts for 40.650 kgr. rails, and also for fish plate bolts for 50 kgr. rails of 9 m. (29 ft. 6 3/8 in.).

34 mm. (1 11/32 inch) diameter for fish plate bolts of 50 kgr. rails of more than 9 m. length, and 27 mm. (1 1/6 inch) diameter for fastening stop plates for 40.650 kgr. rails.

The holes are to be truly cylindrical with the burr removed.

The following tolerances are allowed in drilling the holes :

± 0 mm. 5 (3/128 inch) on the diameter of the fish plate bolt holes;
± 0 mm. 5 (3/128 inch) on the position of the fish plate bolt holes;
± 0 mm. 5 (3/128 inch) on the diameter of the intermediate holes;
± 0 mm. 5 (3/128 inch) on the position of the intermediate holes as regards height;
± 0 mm. 5 (3/128 inch) on the distance between the intermediate holes;
± 3 mm. (1/8 inch) on the position of the intermediate holes from the end of the rail.

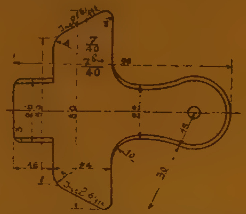
The maker has to provide steel gauges for checking the lengths of all the rails ordered. These gauges are provided with gauge marks for checking the various lengths and should be constructed so as to bear against one end of the rail which is to be checked.

For the lengths between the intermediate holes, the gauges are provided with buttons which enter these holes.

At the commencement of manufacture, each maker is obliged to mark off, by means of a metre scale, a rail of the normal length of 18 m. (59 ft. 5/8 in.) at a temperature of 15° C. (59° F.). This rail, which is marked off metre by metre, remains at the disposal of the Committee during the whole term of the contract and is used for the periodical verification of all the various length gauges.

As regards the drilling of bolt holes, the information given to the manufac-

Drilling intermediate holes, tolerance ± 1/2 mm. (0.0196 inch) on diameter and vertical position of holes.



*N. B.* — For checking the vertical position of the holes, it is necessary to have two gauges: 7/40 having a portion which enters the hole 26 mm. (1 1/32 inch), 7bis/40 having a portion which enters the hole 29 mm. (1 5/32 inch)

*Section C-D.*

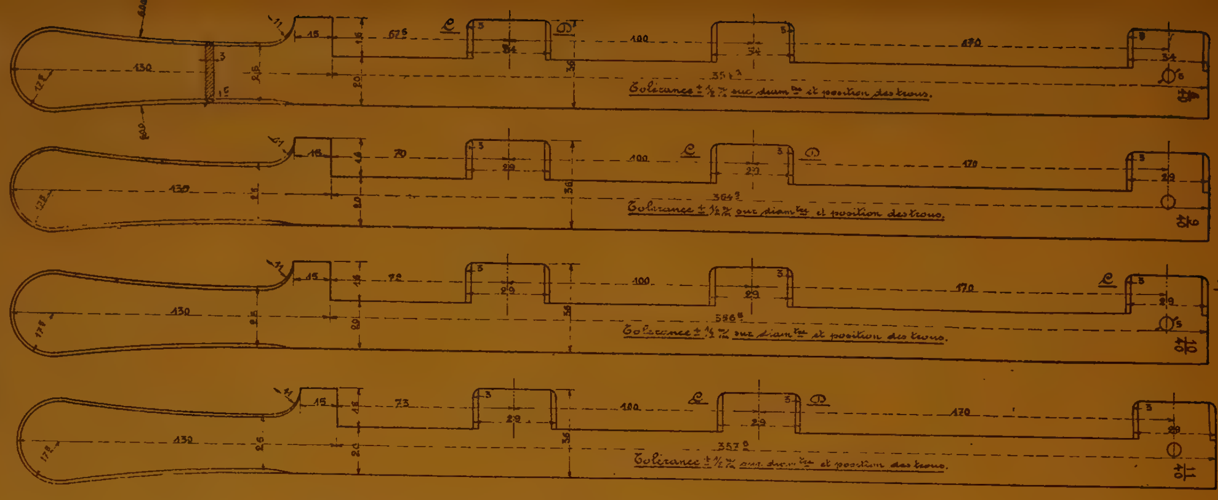
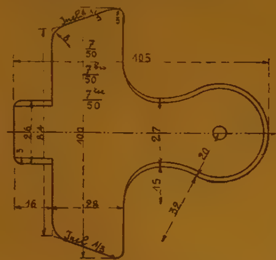


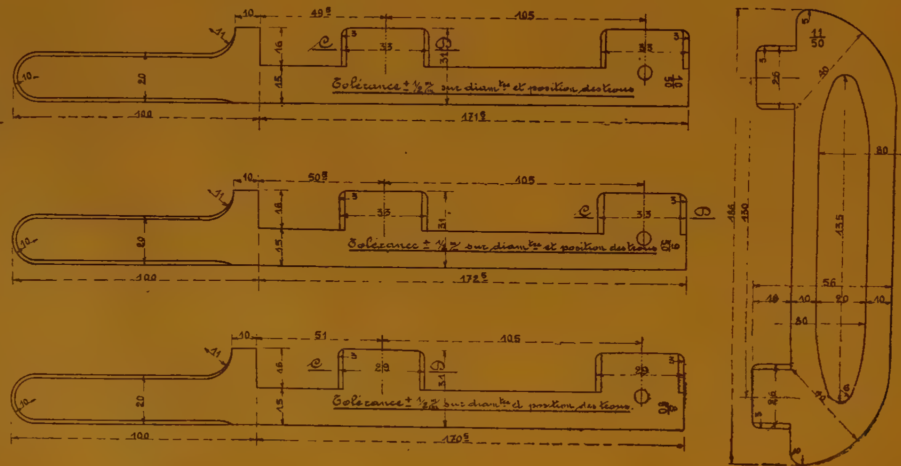
Fig. 21. — 40.650 kgr. per metre (81.94 lb. per yard) rail.

Drilling intermediate holes, tolerance ± 0.0196 inch on diameter and position of holes.



*N. B.* — For checking the vertical position of the holes, it is neccessary to have three gauges:
7/50 having a portion which enters the hole 26 mm. (1 1/32 inch);
7bis 50 having a portion which enters the hole 29 mm. (1 5/32 inch);
7ter/50 having a portion which enters the hole 33 mm. (1 5/16 inch.).

*Section C-D.*



Drilling the intermediate holes [for stop plates) tolerance ± 1/2 mm 0.0196 inch) on diameter and position of holes].

Fig. 22. — 50 kgr. per metre (100.79 lb. per yard) rail.

*Explanation of French terms* : Tolérance ± 1/2 mm. sur diamètre et position des trous = Tolerance ± (0.0196 inch) on diameter and position of holes.

turer with the order states the rails which are to be drilled, either at one end or at the two ends, the rails which are not drilled being those which are intended for the manufacture of points and crossings.

### Finish of rails.

The rails must be perfectly straight throughout their length, no tolerance being allowed. When taken from the rolls, the rails are to be laid out in a covered building sheltered from the weather.

They are to be placed in such a position that the subsequent cold bending shall be reduced to the absolute minimum. Straightening shall be effected without impact by gradually applied pressure.

All the rails are to be milled at the ends so as to have a clean cut section truly perpendicular to their axis. The tolerance by which the ends of the rails may be out of square being 0 mm. 25 (0.0098 inch).

All fins shall be carefully removed and no marks of the hot saw may be allowed to remain.

It is most important to protect the rails from the weather after rolling and from the action of water in order to avoid hardening effect, for this defect is often local and escapes the notice of the inspectors, only revealing itself during straightening at the press or even in service, where it may, by causing a breakage, lead to a very serious accident (1).

The position of the rails when cooling may have a considerable effect on the deformation resulting from contraction. The amount of deformation often depends upon the care taken in laying out the rails after rolling. It is found that when any bends in the rails have to be taken out by means of straightening presses, this may have a serious effect on the state of the rail, effects which may even cause cracks at the junctions of the various parts of the rail, namely, the head, the web and the foot. This defect especially arises from the unskilful use of straightening rolls which act in too drastic a manner.

The other clauses are sufficiently clear not to require any comments.

### Marking the rails.

The rails must bear on both faces of the web and not opposite each other, the makers' mark, the year of manufacture, the order number and the letters ABS or ATS in accordance with whether the rails are of acid Bessemer steel or basic Thomas steel. They are also to be marked with an arrow pointing towards the end corresponding to the head of the ingot.

These marks are made by characters cut in the finishing roll. They are to be as visible as possible without impeding the proper fitting of the fish plates.

The rails must also bear a stamp mark which is stamped hot, giving the cast number from which they are made.

Moreover, the rail which is made from the top part of each ingot is to be hot stamped with the letter T, in addition to the cast number, and also a letter or figure giving the order of the ingots cast successively from each cast number.

The maker must stamp one end of each rail with the cast number from which it is made.

The rails on acceptance shall be stamped by the Committee at both ends.

We will illustrate by the following example the foregoing instructions.

Suppose that a firm, whose distin-

(1) See page 969, a detailed example of localised hardening.

guishing mark is S. J. C., is delivering rails to contract number 20 349 in 1924.

All the rails would bear *in relief* the following marks upon the web :

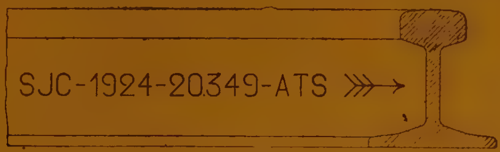



Fig. 23

ATS signifies that the rail is made of Thomas steel with 0.12 % of silicon.

On rails supplied to orders prior to October 1924, one will find the mark ATS2 corresponding to a minimum silicon content of 0.20 %.

An arrow indicates the direction of the head of the ingot.

All the rails made from the heads of ingots are to be hot stamped with the number of the cast from which they are made and also the letter T, together with the serial number or letter of the ingot.

In addition to the above marks, which are rolled on the rails, one will find on certain rails the following marks as for example :

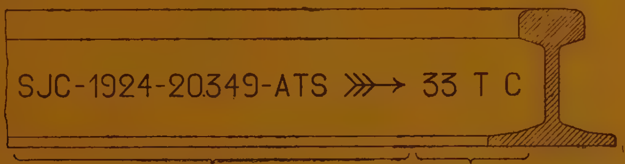



Fig. 24.

33 signifies that the rail is rolled from cast number 33; T indicates that the rail is made from the head of the ingot, and C that it is made from the third ingot from cast No. 33.

For this latter mark it is necessary to take into account the order in which the ingots are cast.

The number of the cast and also the letter T should be stamped cold at one end of the rails presented for inspection.

When the rail breaks or a serious defect is found, it is necessary to take, not only the raised marks or the hot stamped marks on the web, but also the marks stamped on one of the ends. One will find, for example, on the end of the rail (at least if it has not been cut before laying).

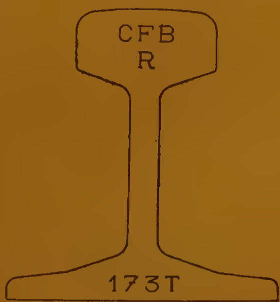



Fig. 25.

CFB is the stamp mark of the administration; R is the inspectors stamp mark who is responsible for inspecting

the material at the works (each inspector has a different letter); T indicates whether the rail is taken from the head of the ingot.

All rails not marked T are supposed to be taken from the lower portion of the ingot.

### Weight of rails.

The normal weight of the rails as given by the theoretical section, as quoted in clause 7 of the existing specifications, is 40.650 and 50 kgr. per metre (81.94 and 100.79 lb. per yard).

In examining rails separately, a tolerance is allowed of 2 % greater or less weight, provided that the whole do not vary from the correct weight by more than 1 %.

Within this limit of tolerance and below, the rails are paid for in accordance with their actual weight; if above, the excess weight is not paid for.

For each batch of rails received, the weight per metre shall be obtained by weighing at least 50 rails of the normal length taken from different casts and selected, half by the manufacturer, and half by the administration.

### Making good defects.

It is strictly forbidden to hammer, heat, or file rails with the object of concealing defects in the manufacture.

Any rails which show marks of being faked in this way shall be rejected.

During the preliminary examination of the rails, it may be that the inspector, to assure himself of the exact nature of certain marks which may be defects, lightly cuts the surface of the rail with a chisel. The workmen have a tendency to hammer out these chisel marks. This practice has certain disadvantages, and it is much better to leave the chisel marks.

## VARIOUS TESTS OF THE MATERIAL.

The rail material must satisfy the following tests:

### Impact tests.

#### 1. Preliminary test.

The Committee shall carry out in the first place an impact test with a falling weight of 500 kgr. (1 100 lb.) for the 40.650 kgr. (81.94 lb.) rail, and 1 000 kgr. (2 200 lb.) for the 50 kgr. (100.79 lb.) rail, the weight falling through a height of 4 m. (13 ft. 1 1/2 in.) *on material taken from the head of all the ingots used in each cast.* These portions of rail, about 2 m. (6 ft. 6 3/4 in.) long, are to be taken from the upper end of each ingot, and shall be cut with a hot saw on one side only, the other side remaining rough.

They shall be marked, while hot, with the cast number to which they refer, the letter T, and also the serial letter or figure indicating which ingot of the particular cast.

If one of these ends should break, *two additional tests* shall be carried out on two ends of about 2 m. long (6 ft. 6 3/4 in.), the first being taken from the rail made from the head of the ingot bearing the same serial number and the same cast. The second being taken from the rail made from the head of another ingot from the same cast. These additional test pieces shall be taken from the end of the rail corresponding to the head of the ingot, and must withstand a blow from the same weight *falling through a height of 6 m. (19 ft. 8 1/4 in.).*

If these test pieces break, all the rails marked T from the same cast number shall be rejected, and falling weight tests from a height of 6 m. shall be continued on the other rails not marked T from the same cast number on two portions of rail 2 m. long taken from two different rails.

If one of these portions of rail break, all the rails of that cast number shall be rejected.

We consider, contrary to the opinion expressed by Mr. Fremont in his interesting article on « Testing of rails », that the test should be carried out in the normal position which the rail occupies in service, that is to say, resting on the foot.

The falling weight tests are carried out on portions of rail 2 m. (6 ft. 6 3/4 in.) long with a tolerance of 10 cm. (3 15/16 inches).

**2. Final tests.**

The Committee shall also select from each batch of rails from 1.5 to 2 % of their number, each rail chosen being from a separate cast or different ingot. The majority of the rails thus chosen shall be marked with a letter T.

From each of these rails and at the end corresponding to the head of the ingot for the rails marked T, two pieces shall be cut, the first about 2 m. long for the falling weight test, and the second 0.75 m. (2 ft. 5 1/2 in.) long from which may be machined the tensile test pieces and also the sections for macrographs and notch bar test pieces. These two portions shall be stamped by the inspector. The portion 2 m. long must resist the impact of the falling weight falling freely from a height of 6 m. (19 ft. 8 1/4 in.). If a portion of rail marked T breaks, two portions of the same length shall be taken from two rails marked T of the same cast number.

If another fracture occurs, all the rails made from the heads of the ingots from the same cast shall be rejected, and two pieces 2 m. long shall be taken from two rails of the same cast not marked T.

If breakage again occurs, the rails from the entire cast shall be rejected, notwithstanding any results obtained in the preliminary tests.

On the other hand, if a portion of rail not marked T used for the falling weight test breaks, two similar pieces are taken from rails of the same cast, as well as two pieces from the rails marked T of the same cast. If any test piece breaks, the entire cast shall be rejected, notwithstanding the results obtained in the preliminary tests.

If, moreover, more than one-tenth of the test pieces used in the final tests do not withstand the prescribed falling weight, the whole of the batch of rails shall be rejected without distinction.

The falling weight constitutes one of the most rigorous tests used in the testing of rails. It is a drastic test which gives a good indication of the quality of the metal.

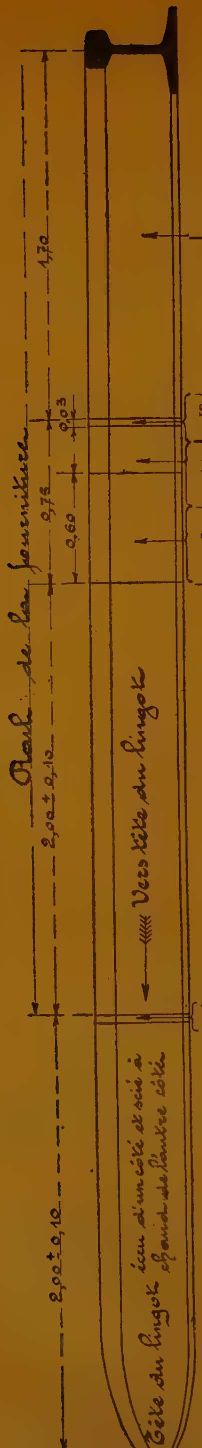
The specification lays down one blow from a height of 6 m. for the ordinary test but the Committee submit each test bar to a second blow from 6 m. so as to satisfy themselves of the ductility and capability of the metal to withstand severe deformations.

This second test is carried out as a matter of interest, but it may on some occasions reveal defects, especially non-metallic enclosures which one blow only would not reveal.

One will find in the appendix attached to the specification the amount of deformation obtained per blow under normal conditions.

**Tensile tests and examination of the fractures.**

From the portion selected for tensile test pieces, macrographs and notched bar test pieces, are cut portions 60 cm. (1 ft. 11 5/8 in.) long for the preparation of tensile test pieces and the examination of




*Explanation of French terms :* Rail de la fourniture = Portion of rail which is used. — Tête du lingot écru d'un côté et scié à chaud de l'autre côté = Head of ingot notched on one side and sawn hot on the other side. — Vers tête du lingot = Towards head of ingot.

Static bending test.

Section to be polished and etched for macrographs and Brinell test on sections specially prepared.

Portion of rail which is cut in the direction of rolling into notched bar test pieces, this being at the end of the portion set aside for the final impact and tensile tests.

Tensile test to be taken from the end of the portion selected by the Committee to be submitted to the final impact test (from the head).

Falling weight test from 6 m. (19 ft. 8 1/4 in.) carried out by the Committee on a certain number of rails, 1.5 to 2 °/₀ of *the rails offered* and required to be subjected to the whole series of mechanical tests.

Section for macrograph (additional test).

Falling weight test from 4 m. (13 ft. 1 15/32 inch) on all the portions cut from the head of ingots of each cast. (Sawn hot on one side only).

Fig. 26. — Table showing the position from which the various test pieces are taken.

the fractures under the following conditions :

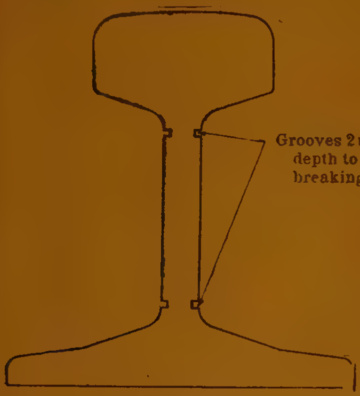



Fig 27.

This piece of metal 60 cm. long, is in the first place broken into three parts horizontally, the first break where the head is joined to the web, and the second where the foot is joined to the web. The breaks are prepared by notches, being made 2 mm. (5/64 inch) in depth as a maximum, these being either cut with a set or machined.

Each of these portions, head, web and foot, are stamped by the inspector with the number of the cast from which the portion of rail is made.

The fractures should show a fine uniform grain which is homogeneous and free from brilliant white spots.

From each portion of the head of the rail, tensile test pieces are then machined having a diameter of 16 mm. (5/8 inch) and an effective length of 200 mm. (7 7/8 inch) between the gauge marks as shown on the general drawing of gauges and test pieces, which shows the exact portion of the rail section from which the test piece is to be taken (figs. 28 to 31).

In addition to the turned test pieces, the outside portions of the head are kept so that they may be broken in the presence of the Committee.

The diameter of the test pieces should be correct to within 0.05 mm. (0.00196 inch) above or below the nominal size.

The length of the ends of the test pieces shown as 70 mm. (2 3/4 inch) may be reduced where necessary to suit the jaws of the testing machine, but the test pieces used at Malines are always as shown on the drawing.

The ultimate tensile strength of the test pieces shall not be less than 70 kgr. per square millimetre (44.4 tons per square inch), and the elongation should be at least 10 %. Moreover, the index of quality obtained by adding the tensile strength (metric units) to twice the elongation should be greater than 94.

The elastic limit and the reduction of area are recorded for each test piece broken.

If the test pieces do not satisfy the conditions imposed, either by having too low a tensile strength or insufficient elongation, the rails corresponding to the cast numbers concerned shall be rejected.

However, before the rails are definitely rejected, additional tests shall be carried out, either at the maker's works or at the test office at Malines, under the same conditions as those laid down under the heading « Acceptance of rails ».

The test pieces which are cut from the rails not marked T, that is, from those made from the lower portion of the ingots, may in some cases be taken from the portion cut from the end of the rail at the maker's risk.

The separation of the portion of rail into three pieces, head, web and foot, has the advantage, not only of allowing the fractures to be inspected, but allows the Committee to take an additional flat ten-

The length of the end portion 70 mm. (2 3/4 inch) long may be reduced to 25 mm (1 inch) in accordance with the type of grips used in the machine.

Fig. 28.

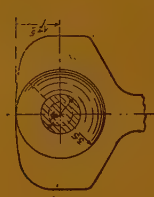


Fig. 29. — 40.650 kgr. rail. Position from which tensile test piece is taken.

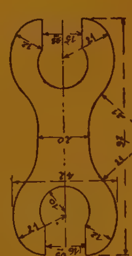


Fig. 30. — Gauges for checking tensile test pieces.

Fig. 31. — 50 kgr. rail. Position from which tensile test piece is taken.

Figs. 28 to 31. — Tensile test pieces.

sile test piece or bending test piece from the web.

The longitudinal axis of the test pieces is approximately at the centre of the head. This position corresponds to that where segregation is liable to be found, and the maker is therefore compelled to cut sufficient from the end of the rail, as the rails are to a certain degree judged by the results of the tensile test.

The length of the ends of the test pieces has been fixed at 70 mm. so that they may be effectively gripped by the jaws of all the testing machines. A certain number of these are provided with wedge grips and require a greater length of head. In the case of other machines with toggle jointed jaws, the length of the ends may be reduced to 25 mm. (1 inch). This facilitates the machining of the test pieces and provides a better grip while reducing the overall length.

As regards the tensile strength and elongation, which are fixed at 70 kgr. per square millimetre and 10 % respectively, it is stipulated that the sum of the resistance plus twice the elongation should be greater than 94 so as not to depend upon the minimum tensile strength and elongation.

Steel which has a tensile strength of 70 kgr. must therefore have an elongation of more than 12 %.

On the other hand, we have laid down in a circular to the contractors that they must keep as far as possible within the limits of 70 to 80 kgr. per square millimetre (44.4 to 50.8 tons per square inch) for the tensile strength. This instruction has mainly arisen in view of the results previously obtained at certain works where steel has been made having a tensile strength as great as 90 kgr. (57.1 tons per square inch). Although fulfilling the conditions of the specifi-

cation as regards elongation and falling weight test, these rails have given rise to serious trouble when being bent and to difficulties in manufacture when making points and crossings requiring especially a reduction in the cutting speed of the machine tools.

Moreover, very high tensile strength appears to us to be dangerous for ordinary rolled steel sections. It also appears well established that the resistance to wear is not directly dependent to tensile strength when dealing with hard steels.

By elactic limit is implied the apparent elastic limit, that is to say, the stress at which the permanent elongation of the test piece commences.

The reduction in area which gives useful information on the ductility is noted in all the tests. It is obtained by the following formula

$$\frac{S - s}{S} 100$$

where S is the initial section, and $s$ the section after fracture.

As a matter of information, we give the requirements in various foreign countries as regards tensile tests.

It may be pointed out that the figures given in this table are only comparable provided that one takes into account the differences in the dimensions, length and diameter of the test pieces.

| COUNTRY. | Class of steel. | Process of manufacture. | Minimum tensile strength per square millimetre, in kilograms (per square inch, in tons). | Minimum elongation per cent. in millimetres (in inches). | *Remarks.* |
|---|---|---|---|---|---|
| *France.* | Ordinary carbon. | Bessemer or Siemens Martin acid or basic. | 65 (41.3).<br>70 (44.4).<br>80 (50.8). | 10 %<br>9 %<br>7 % | $R + 2A \geqslant 92$<br>$R + 2A \geqslant 94$<br>$R + 2A \geqslant 98$ |
| *England B. S. S.* | Ordinary carbon. | Siemens Martin or Bessemer acid or basic. | 66.14 to 78.74 (42 to 50)<br>over 78.74 and up to 83.47 (50 and up to 53). | 12 to 15 % (10). | The mimimum elongation for intermediate tensile strengths being proportional. |
| *England B. S. S.* | High carbon steel. | Siemens Martin acid or basic. | 72.44 to 78.74 (46 to 50)<br>over 78.74 to 86.62 (50 to 55). | 12 (10). | ...<br>... |
| | | Bessemer acid. | 69.29 to 78.74 (44 to 50)<br>over 78.74 to 83.47 (50 to 53). | 12 (10). | ...<br>... |
| *Germany.* | Ordinary carbon. | ... | 60 kgr. (38.1). | ... | ... |

### Macrographic tests.

From the remaining portion of the piece of rail used for tensile macrographic and notched bar test pieces is cut a section of rail 3 cm. (1 3/16 inch) thick. This piece is carefully polished on one face to allow a macrograph to be taken. This should not show any trace of segregation.

The Committee also take macrographs on a section cut at the end of a certain number of pieces cut from the ends of rails selected by them.

The Committee may, if they think fit, omit to make macrographs of rails produced from the lower portion of the ingots.

The necessary materials and plant for these tests shall be provided by the contractor, and he shall be informed in good time beforehand of what will be required.

In the case where some of these macrographs show the presence of any segregation or inclusions, the Committee shall demand, according to circumstances, either that another section shall be cut or that the rails made from the top portion of the corresponding ingots shall be withdrawn and further macrographs taken on other rails made from the top portion of the ingots.

If the number of rails showing segregation exceeds 10 % of the total number of macrographs taken, all the rails in the batch made from the top portion of the ingots shall be rejected.

The macrographs consist of an investigation of polished surfaces which are etched by means of a suitable reagent, the time taken depending upon the constituents in the metal under investigation. It is a corrosion test which can be carried out with the naked eye or with a magnifying glass, but without the use of a microscope.

The reagents which are most generally used for rail steels are :

*Heyn's reagent.*

| | |
|---|---|
| Double chloride of copper and ammonia . . . . . . . . | 12 gr. (6.77 drams). |
| Distilled water . . . | 120 cm³ (7.32 cubic inches). |

*Iodine reagent.*

| | |
|---|---|
| Sublimated iodine. . | 10 gr. (5.64 drams). |
| Potassium iodine . . | 20 gr. (11.28 drams). |
| Distilled water . . . | 100 cm³ (6.10 cubic inches). |

(We also employ other reagents — Stead, Le Chatelier, Oberhoffen — in cases where micrographs are subsequently to be taken.)

For testing rails, we may say that the macrograph provides a very valuable test capable of giving information which cannot be given by the other tests laid down in the specification.

Experience has shown that of all the rails which have broken in service due to the quality of the metal, nine-tenths of the cases may be attributed to the presence of piping, zones of segregation, or non-metallic enclosures, that is to say, have arisen through insufficient having been cut from the unsound portions of the ingots. A few other cases have arisen from the metal having become oxidised during its manufacture.

The influence of piping, segregation and non-metallic enclosures, on the breakage of rails has been very carefully investigated by Mr. Ch. Fremont in his papers Nos. 58, 61 and 69 : *Causes d'usure prématurée des rails* (*Causes of premature wear of rails*), Paris, 1921; *Causes de ruptures accidentelles de rails* (*Causes of accidental breakage of rails*), Paris, 1923, and *Usure et défauts de rails* (*Wear and defects in rails*), Paris, 1924.

We will confine ourselves to drawing

the attention of the reader to these papers.

We give two photographic reproductions of macrographs taken with double chloride of copper and ammonia on sections of rails which show zones of segregation.

Fig. 32.

Fig. 33.

A macrograph by means of the double chloride of copper and ammonia may, moreover, in addition to the valuable information as regards segregation, give information on the structure of the steel and reveal isochemical zones in the rail which give rise to different colouration of the macrograph, zones of varying carbon content being characteristic of rails which have been rolled at too high a temperature.

These zones show themselves in the section of the rail in the form of an image which it is difficult to reproduce photographically, but which we show diagrammatically in figure 34.

The notched bar tests and the micrographs confirm, by the condition of the structure, the variations in the carbon content. These zones are not always clearly defined, but may vary gradually in the case of portions of metal from different sources which have been perfectly welded. The web of the rail shows a decarbonisation caused by a precipitation of the ferrite. One therefore obtains from the web a greater resistance to impact than in the case of metal from the head or base.

These zones spread out in the head of the rail and structural anomalies may, in view of the position from which the tensile test piece is taken, lead to variations in the strength and elongation of

the test piece and give abnormal results in accordance with the way in which these zones are located in the section tested. We have also, on a number of occasions, found that after breaking the tensile test piece, there are minute cracks on one side only, showing that this part has been extended to a degree exceeding its ductility, which is less than that of the neighbouring metal.

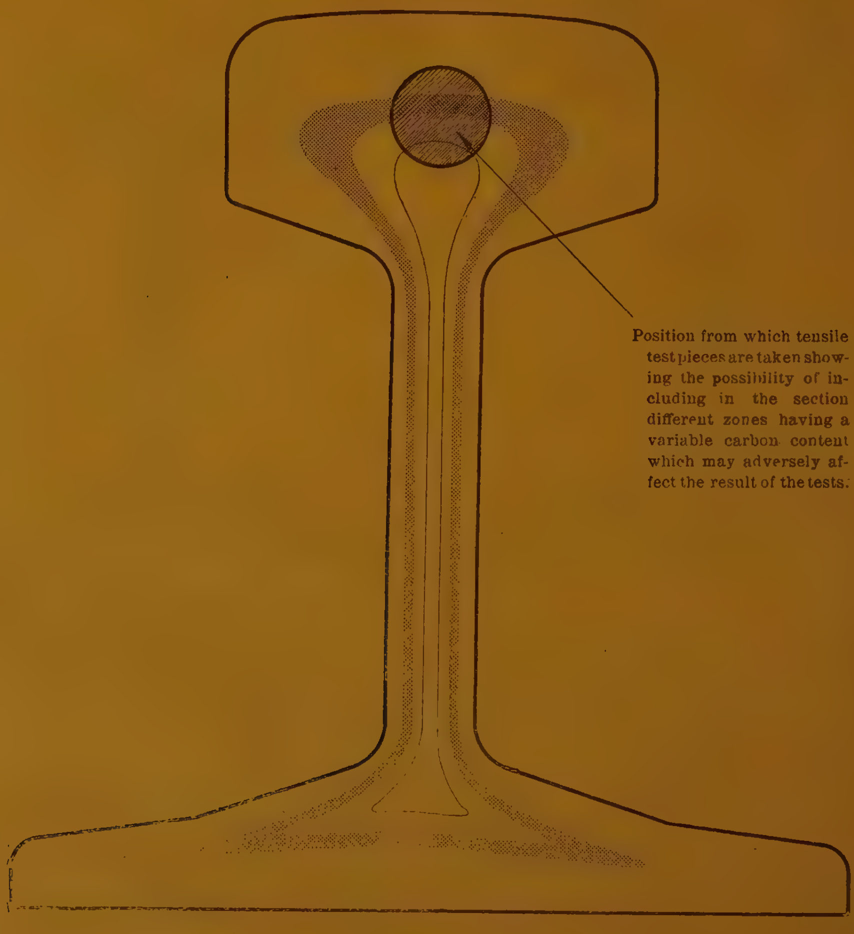



Fig. 34.

In practice, the alternating bending stresses to which the rails are subjected may give rise to effects of the same nature, and it is undesirable that such trouble should be regarded, as is often the case, as being due to a « defect ».

* * *

We also carry out at the same time, for the determination of impurities and inclusions of sulphur, macrographs by the Baumann process, which consists of applying for from 2 to 5 minutes, on the polished surface of the rail, a paper sensitised with bromide (or citrate) of silver previously soaked in distilled water and afterwards dipped for a few moments in sulphuric acid at 3° Baumé.

This method shows up the parts of the section which contain sulphur.

The print which is fixed with hyposulphite of soda after washing in water gives as a rule an image which is identical with that obtained by means of the Heyn reagent.

The sulphur segregated portions of the steel are attacked by the acid solution and liberate sulphuretted hydrogen which converts into black sulphide the bromide of silver with which it is in contact.

Certain writers have stated that this method also reveals the presence of phosphorus, but the opinion of Mr. Henry Le Chatelier, which is confirmed by the more recent researches of Oberhoffen and Knipping in Germany, seem to have established that the Baumann process only reveals sulphur.

We show in figures 35 and 36 two bromide prints under which we give the results of a chemical analyses of the head and web of two rails broken in service by a portion of the head becoming detached along the lines of impurities.

### Micrographic tests

The Committee, whenever they consider it necessary, also make a micrographic examination of the rails offered for inspection. These examinations are intended to obtain information as to the structure of the metal and its uniformity throughout the whole of the rails supplied. These tests also serve to verify whether the temperature at which rolling has taken place has been suitable.

We have made a practice of making micrographic examinations both for the structure of new rails and also as a means of investigating the causes of rails having broken in service. This method very often allows one to obtain clear evidence of the influence on the structure, either of the processes of manufacture or the stresses which the rail has been subjected to in service.

We show in figures 39 to 44 a series of micrographs showing the normal structure of our rail steel.

We may mention that as a rule we use metal left over from the notched bar test pieces, which greatly facilitates the preparation of the specimens.

### Notched bar tests.

The notched bar tests are carried out by the Committee as a means of obtaining useful information. They are carried out by means of a 30 kilogrammetre (217 foot-pound) Charpy pendulum (see figure 45). The necessary test pieces are prepared at the maker's cost. These test pieces should be prepared at the same time as the other test pieces required for the acceptance of rails.

The test pieces are taken as follows :

From the remainder of the portions of rail 75 mm. (2 15/16 in.) in length which have been used for the tensile test pieces and for the sections used for the macrograph, there are also machined *in the direction of rolling* three notched bars as shown on the general drawing of gauges and test pieces. The section of these bars and the dimensions of the notch are checked by means of a limit gauge having tolerances of $\pm$ 0 mm. 1 (1/256 inch).

The position of the notch is also given on the drawing. Each series of test

Fig. 35.

Chemical analyses

| in the head. | in the web. |
|---|---|
| S = 0.042 % | S = 0.06 % |

Fig. 36.

Chemical analyses

| in the head. | in the web. |
|---|---|
| S = 0.042 % | S = 0.074 % |

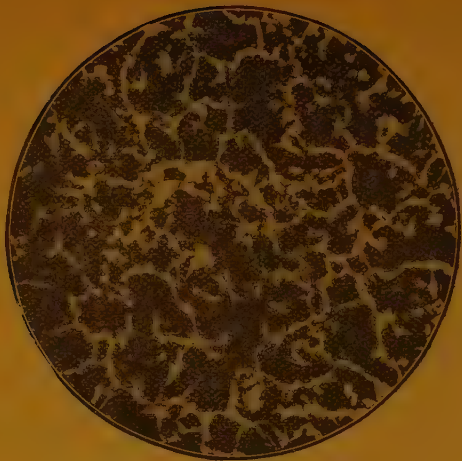
Fig. 37.

This Baumann print was obtained from the same portion of rail as was the Heyn print, the similarity of the results obtained will be noted. (See fig. 33.)

Fig. 38.

100 ×

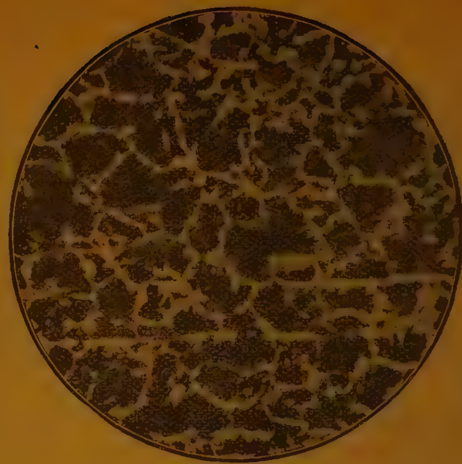
*Per-pendicular to the direction of rolling.*



*Analysis of the cast.*

C = 0.46
Si = 0.14
S = 0.054
Ph = 0.062
Mn = 0.90

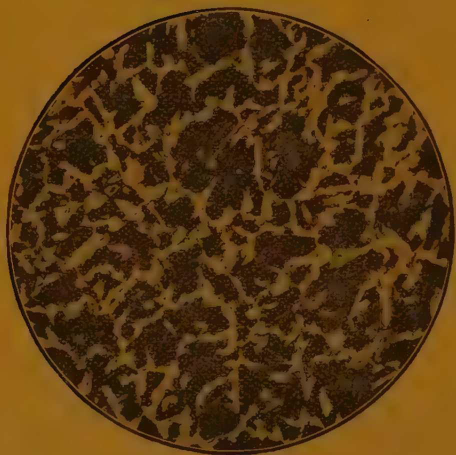
100 ×



*Parall to the directi of rolli*
R/kgr. m
= 78.
(tons
per sq.
= 50)
Elongat
°/₀ = 1
ρ=4.16/c
(0.643 sq.

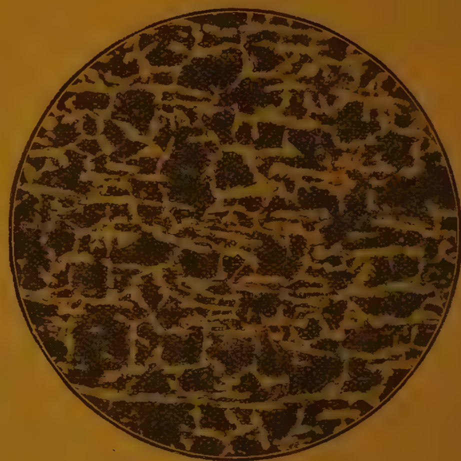
100 ×

*Per-pendicular to the direction of rolling.*



C = 0.43
Si = 0.16
S = 0.054
Ph = 0.06
Mn = 0.95

100 ×



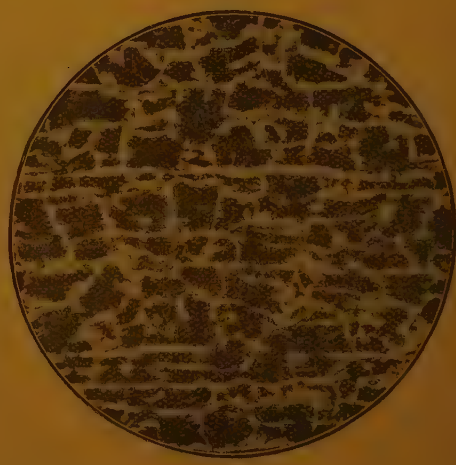
*Parall to th directi of rolli*
R/kgr./n
= 77.
per sq.
= 49.3
Elongati
°/₀ = 1
ρ=4 94/c
(0.765 sq.

100 ×

*Per-pendicular to the direction of rolling.*

C = 0.42
Si = 0.16
S = 0.05
Ph = 0.07
Mn = 0.95

100 ×



*Parall to the dir ctio of rolli*
R/kgr./n
= 75
(tons
per sq.
= 47.
Elongat
°/₀ =
ρ=4.41/
0.683 sq.

Figs. 39 to 44. — Some micrographs showing normal structures of rail steel.

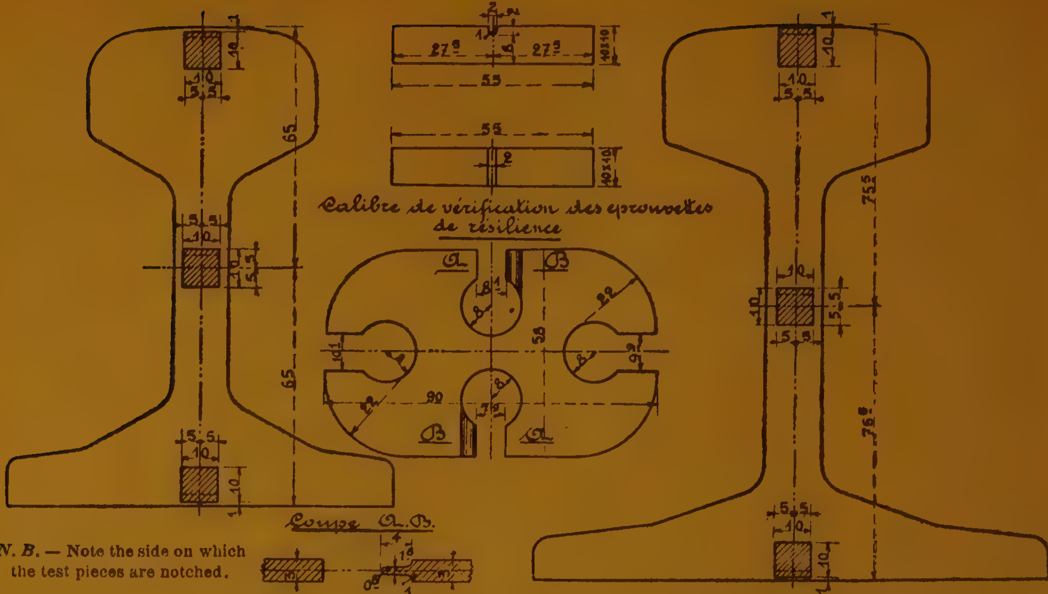
pieces shall be stamped with the corresponding cast number, and this number is followed by the letter A, B or P indicating whether the test piece is taken from the web, head or foot of the rail. (See figures 46 to 49.)

Fig. 45. — Charpy pendulum.

We will not enter into the various discussions which have taken place with the object of finding the best form of notch to be cut in bars for these tests and the ratio which may be established between the results of dynamic tests and the other physical or chemical tests.

It is sufficient to say that we have

*Notched bar test pieces.*




*N. B.* — Note the side on which the test pieces are notched.

Figs. 46 to 49. — Position from which notched bar test pieces are taken.

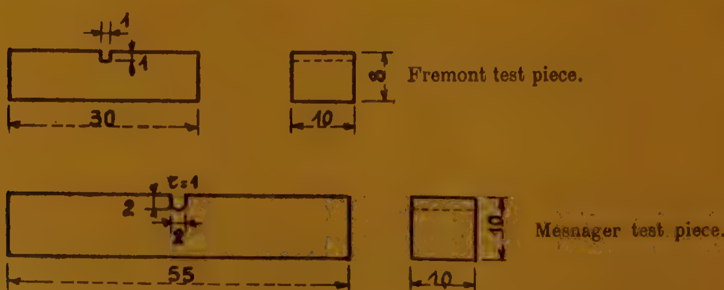



Fig. 50.

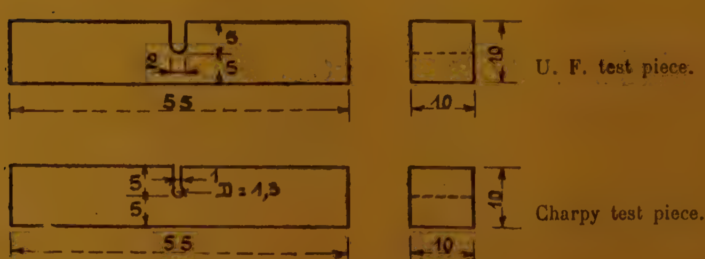



Fig. 51.

Figs. 50 and 51. — Types of notched bar test pieces.

*Explanation of French terms :* Calibre de vérification des éprouvettes de résilience = Gauge for checking notched bar test pieces. — Coupe A. B. = Section A B.

adopted the Mesnager type of notch on account of the ease with which the test pieces can be prepared (see figure 50). Formerly we used the Charpy test piece (see figure 51), but the difficulties of preparation have led us to abandon this type in favour of the Mesnager notch which can be made very easily and accurately in a milling machine.

The notch appears to us to be necessary because it is required to break the test piece without risk of merely bending it.

The degree of brittleness appears to us to be more clearly shown with the notched bar.

What we also wish to obtain from this test is to be able to establish, other things being equal, for the different makers, a comparison of the brittleness of our rail steel without wishing to make a comparison with other steels obtained under other conditions of manufacture or specification.

A number of firms at first expressed doubt as regards the value of this test when carried out on hard steels which have not been heat treated. It has been stated that it is costly to prepare the test pieces, and that the results of the test do not justify this expense. However, our experience has proved that this test has for ordinary rail steels an importance which cannot be neglected as a means of ascertaining the quality.

It is on much the same footing as the micrograph tests, and it is an important fact that at the beginning, when we pointed out to certain makers that the figures obtained for the resistance to impact were very low (often less than 1), a detailed examination of all elements affected by heat treatment led to a very appreciable improvement in the figure. In this way it is now usual at many of the works to *regularly* obtain impact test figures of from 2 to 5. This is a proof of what can be accomplished by careful observation of facts.

The results obtained from a batch of rails which have been inspected will be found in the list of results at the end of this article.

We would draw attention to the necessity for careful preparation of notched bar test pieces. Results which are to be of any value can only be obtained from well made and correctly dimensioned test pieces. *It is also important to take care that the notch is cut in the face of the test piece as shown on the drawing.* Up to the present, although the notched bar tests are compulsory, they are done as a means of obtaining information, and no definite figure is specified, but it is probable that in the near future a *minimum* figure will be fixed. A figure which appears to us to be most suitable for our requirements is about 2 kgr. per square centimetre (28.45 lb. per square inch) as a minimum.

**Brinell tests.**

We carry out on each batch of rails Brinell tests with a pressure of 3 000 kgr. (6 600 lb.) on a ball 10 mm. (3/8 inch) in diameter in order to ascertain the hardness and homogenity of the steel, at various points in the section.

The positions where these tests are carried out are shown on figure 52.

**Static bending tests.**

The Committee shall select, after taking into account the complete results of the first test under a blow of 4 m. (13 ft. 1 1/2 in.) certain rails which have given the greatest amount of deflection, from which are taken lengths of about 1 m. 70 (5 1/2 feet).

These rails, resting on their feet on two supports 1 m. 10 (3 ft. 7 5/16 in.) apart, must sustain for 5 minutes a load of 35 t. for the 50 kgr. (100.79 lb. per yard) rails, and 25 t. for the 40.650 kgr. (81.94 lb.) rails applied at a point midway between the two points of support without taking any permanent set after the removal of the load.

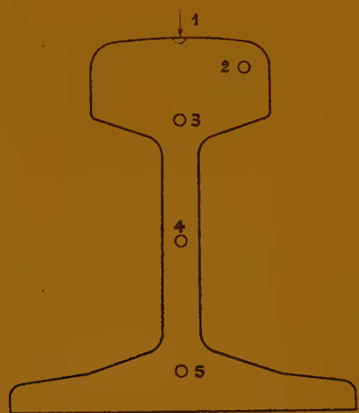



Fig. 52.

If there should be a permanent set, the Committee shall decide, by a consideration of the various results obtained from all the other tests, whether the rails of that particular cast can be accepted by the administration.

This test does not appear to us to be of any great value in determining the quality, because it cannot give any direct indication as regards the condition of the metal. Moreover, it may often occur that the end of the rail submitted for test has already been subjected to a permanent deformation during the process of straightening. One cannot therefore claim that any true indication is given by this static test, and this test will probably be deleted from the contracts in the future.

## RESPONSIBILITY OF MANUFACTURERS.

There is not in the Belgian State Railways' specification any clause regarding a guarantee of the rails, nor any means of establishing the responsibility of the steel makers for rails which break owing to a defect in the metal. The majority of railways impose in their specifications a guaranteed period ranging from six months to five years; other equally important railways are of the opinion that the fact of having submitted the rails to all the tests which they stipulate frees the manufacturer from any further responsibility, the more so because it is always very difficult to obtain agreement as to the cause of a rail breaking. If the penalty incurred by the manufacturer extends no further than the replacement of the rail, it must be admitted that the question is not one of great importance. If, however, it is intended to fix legal responsibility in the case of an accident, this may entail an increase in the cost of the rails quite out of proportion with the improvement in the quality, and it is to be feared that the manufacturers who have to undertake this responsibility will increase their prices in consequence. There does not appear any reason why special rules should be adopted for rails, whereas for articles which are more difficult to control and the breakage of which may lead to more serious accidents, no special provision is made other than those contained in the common law.

## CONCLUSIONS.

It will be seen from the foregoing that in completely revising the specification for rails, the railway administration has aimed at the two following objects :

1) To eliminate as far as possible de-

fective rails containing segregation or traces of piping resulting from cutting too little from the ingots;

2) To lay down tolerances on the sections and dimensions of rails in order that these may be more uniform to ensure a better fit of the fish plates and joints, and to facilitate the manufacture of points and crossings.

* * *

It is obviously too soon to be able to give any definite opinion as to the results which can be obtained with this new specification, but it is certain that its application will tend to improve the quality of the rails supplied.

It should be mentioned here that the makers have not only made the necessary effort to satisfy the conditions laid down, but have shown their willingness to comply with certain requirements which the Committee have asked for on various occasions in the course of their work.

Whereas as regards the tolerances on the section, the breaking tensile stress, the falling weight test and the amount of deflection, the requirements are clearly defined, this is not so in the case of the reduction of area, the elastic limit and the resistance to the notched bar test.

The present state of our knowledge does not allow us to definitely fix minimum figures for the steel now manufactured. It is, however, possible, and we may even say probable, that in the more or less near future the impact test with a Charpy pendulum, or such similar method, will form the first test for passing rails.

We are therefore far from considering this article as being final, and if we have decided to publish it with the necessary data, it has been the object of showing, especially to engineers who use rails, the efforts made with a view to improving the quality of the product by the application of modern and scientific methods of control.

# SUPPLEMENTARY NOTE

## I. — Breakage of rails.

As we have said in the introduction of this article, we have thought it well to give the reader who is unfamiliar with this question an idea of the importance which is to be attached to having rails which are as free from brittleness as possible, and to reproduce diagrams which show for the five sections of the Belgian State Railways the number of breakages for the year 1923.

These show the number of breakages or cracks found per month, either in the part enclosed by the fish plate or in the free portion of the rail, and in each case the total number is given. These figures have been taken from statistics prepared from the reports of the Maintenance Department. The exact causes may be difficult to establish in every case because a number of factors must be taken into consideration. For example, the weak section of a 38 kgr. (76.60 lb. per yard) rail for the heavy axle loads which it has to carry, the neglected state of maintenance during and after the German occupation, the insufficiently strong fish plates of the 52 kgr. (104.82 lb. per yard) rails, the rapid restoration of the lines which was carried out after the armistice, have caused numerous breakages, but our investigations have clearly shown that a great number of breakages or other failures may be attributed to the presence of piping or segregation in the rail.

It must also be understood that the way in which the statistics are drawn up is not perfect and sometimes may give incorrect information. This we believe is the case on a number of railways, and therefore we consider that it would be of greater interest in investigating the causes which lead to rail breakages and therefore to the means by which these can be improved, to proceed in a systematic manner in preparing statistical ratios. In view of the relatively small number of breakages on each railway taken separately, and the necessity of recording all the causes which may have an influence on the various types of fractures, all the administrations should coordinate their method of investigation in order that they may obtain statistics which are comparable one with the other.

## II. — Examination of two cases of broken rail.

It appears to us of interest to those of our readers who are unfamiliar with this question to show how investigations in the laboratory allow the cause of the majority of fractures to be determined in an almost certain manner.

We have chosen for this purpose two examples, one of which refers to the question considered in the first part of the article in the paragraph dealing with the straightening of rails, namely, localised hardening, and the other to a case of a rail of unsound metal.

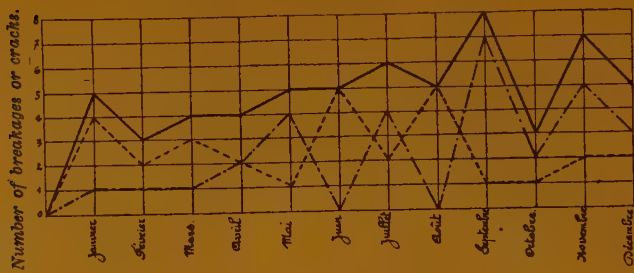
### 1. Localised hardening.

In the month of August 1923, it was found that a 40.65 kgr. (81.94 lb. per yard) rail which had been delivered, but had not been put into service, showed

*57 kgr. (114.90 lb. per yard) rail.*

Kilometres (miles) in service : { Main lines...... 1 032.800 km. (641.763 miles). Branch lines.... 31.473 km. (19.556 miles).

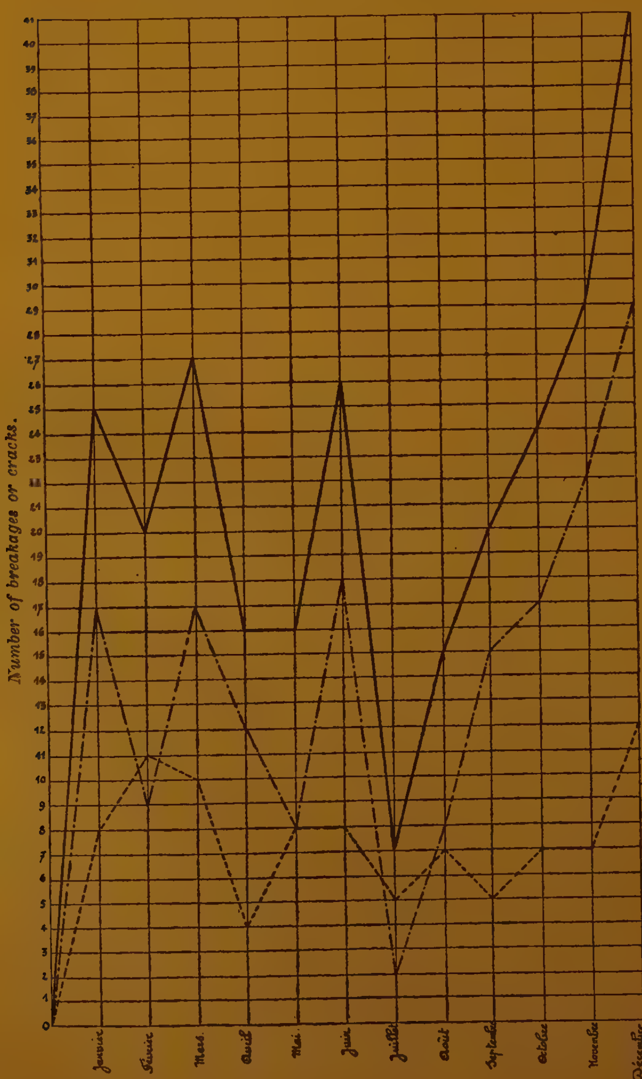
*Total number of breakages for the year : 60.*




*52 kgr. (104 82 lb. per yard) rail.*

Kilometres (miles) in service : { Main lines..... 1 908.317 km. (1 185.764 m es.) Branch lines... 470.007 km. (292.054 miles).

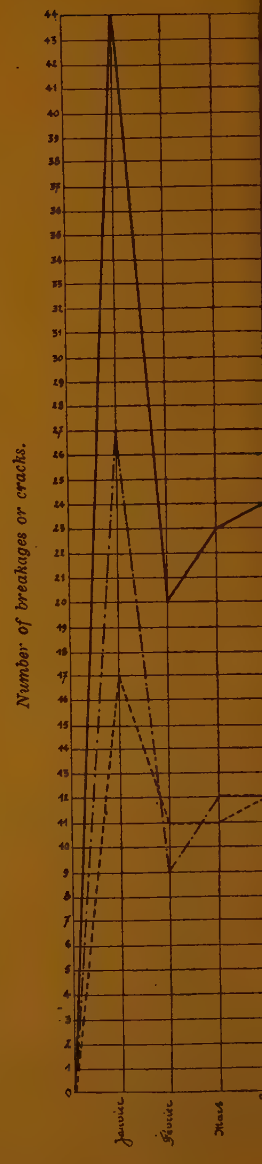
*Total number of breakages for the year : 266.*




*40 kgr. 650*

Kilometres (miles) in service :

*Total number*




EXP

Breakages

Breakages

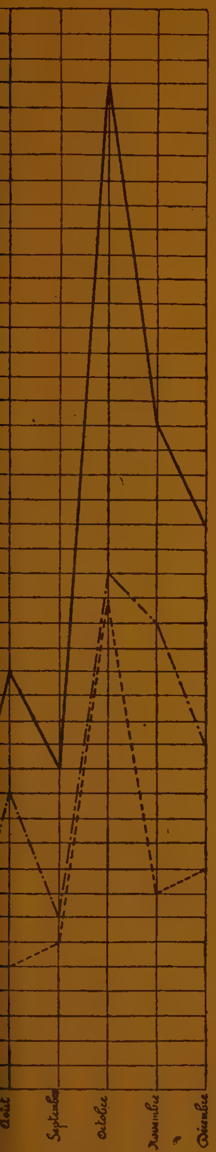
Total.

Fig. 53. — Diagrams show

) rail.

34.674 km. (3 314.870 miles).
70.431 km. (540.870 miles).

year : 266.



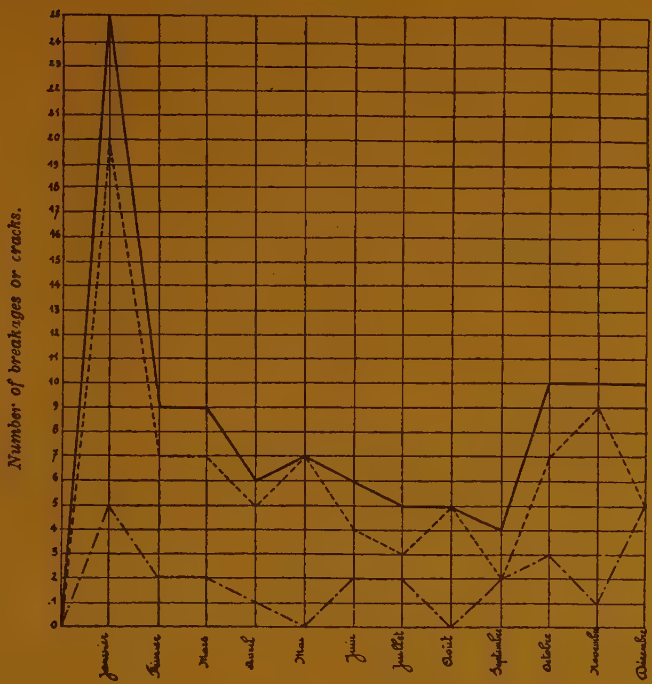

:

ered portion of the rail.

*38 kgr. (76.60 lb. per yard) rail.*

Kilometres (miles) in service : { Main lines....... 987.125 km. (613.381 miles).
Branch lines..... 5 054.093 km. (3 140.522 miles).

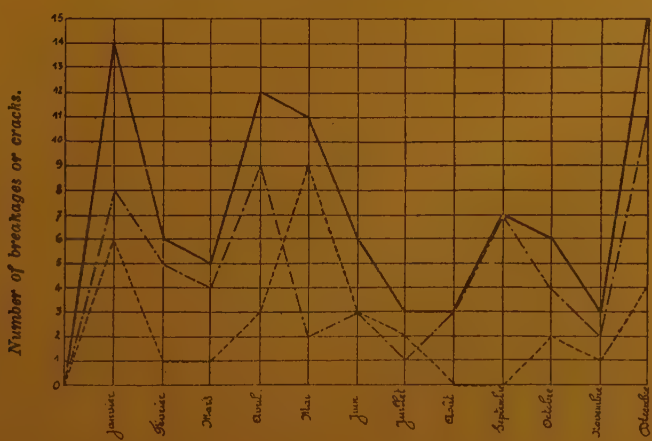
*Total number of breakages for the year : 106.*




*50 kgr. (100.79 lb. per yard) rail.*

Kilometres (miles) in service : { Main lines....... 3 286.803 km. (2 042.360 miles).
Branch lines..... 264.288 km. (164.224 miles).

*Total number of breakages for the year : 91.*




ken rails for the year 1923.

at a particular point six transverse cracks more or less deep on its upper surface.

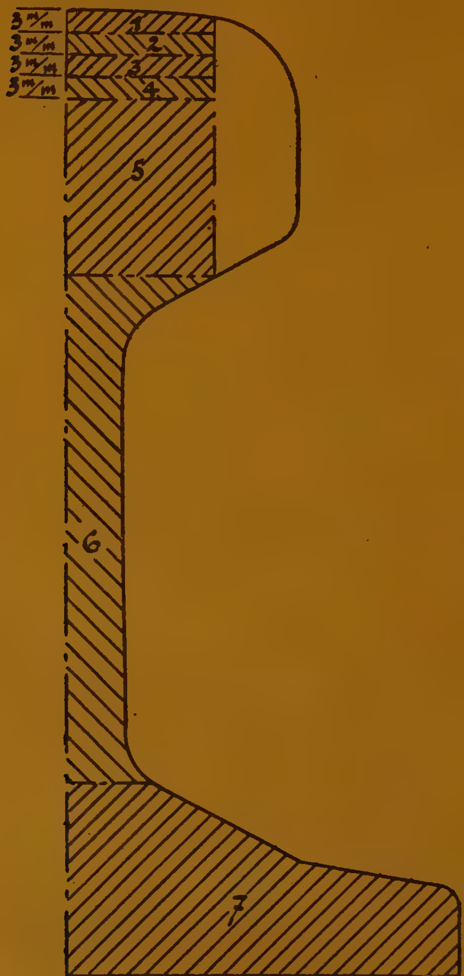



Fig. 54.

An enquiry into the cause of this defect gave the following results :

Prints made by the Baumann process showed that these cracks could not be attributed to segregation extending to the outer layers of the head.

The chemical composition of the metal in the portions marked numbers 1 to 7 was determined.

The analysis was as follows :

| Nos. | C. | Si. | Mn. | S. | P. |
|---|---|---|---|---|---|
| 1 . . . | 0.48 | 0.23 | 0.85 | 0.042 | 0.065 |
| 2 . . . | 0 49 | 0 21 | 0.85 | 0.042 | 0.070 |
| 3 . . . | 0.48 | 0.21 | 0.90 | 0.042 | 0.070 |
| 4 . . . | 0.45 | 0.20 | 0.85 | 0.035 | 0.080 |
| 5 . . . | 0.46 | 0.22 | 0.85 | 0.052 | 0,070 |
| 6 . . . | 0.45 | 0.21 | 0.85 | 0.052 | 0.068 |
| 7 . . . | 0.46 | 0.21 | 0.85 | 0.050 | 0.064 |

The defects in the rail could therefore not be attributed to a lack of homogenity of the metal.

Micrographs were taken from the head of the rail :

*a*) in the cracked portion,

*b*) from the same rail in the sound portion at a distance of about 23 cm. (9 inches) from the last crack.

Figure 55 shows the way in which these test pieces were taken.

The face of the specimen which was polished was that corresponding to the upper surface of the rail.

We will call A the specimen taken from the cracked portion and B that taken from the sound portion.

These specimens were etched for one minute in a solution of 2 % nitric acid in ethyl alcohol.

We obtained the micro-photographs shown in figures 56 and 57.

These micrographs showed two totally different structures :

A, showing a martensitic structure; while

B is composed entirely of ferrite and pearlite.

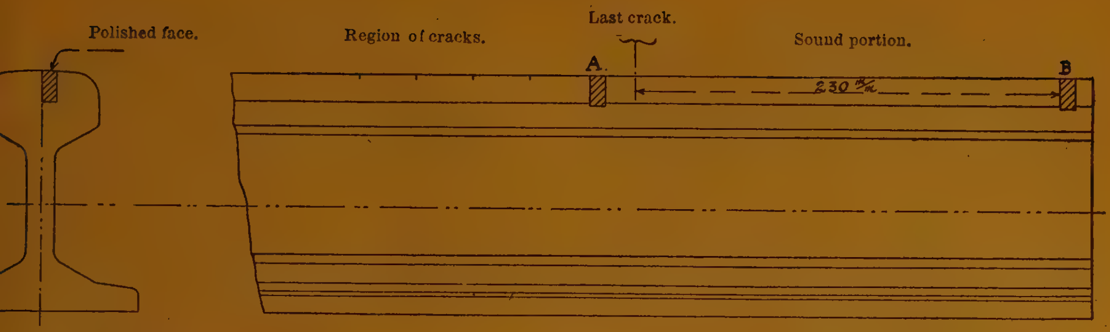
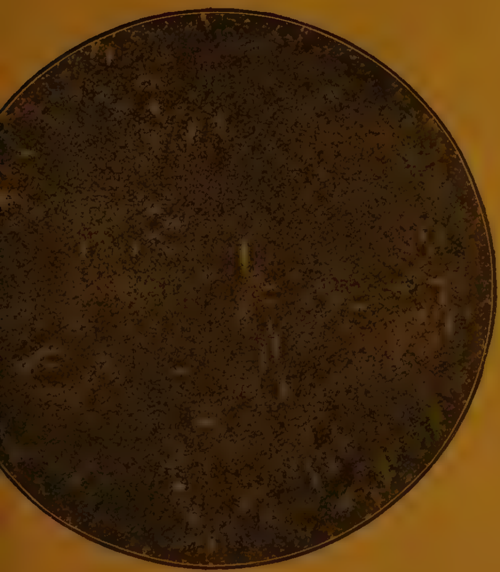
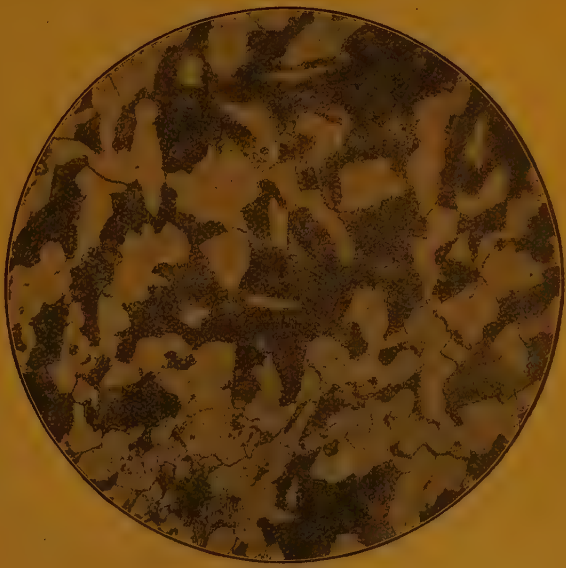



Fig. 55.



Specimen A. — 400 ×

Fig. 56.



Specimen B. — 400 ×

Fig. 57.

Structure A could be due, either to the *accumulation on the upper surface of the rail of a constituent which would cause this structure*, manganese for example, or is due to *hardening*.

The first hypothesis is not confirmed by the chemical analysis.

We therefore have to accept the second hypothesis. As a matter of fact, after re-heating out of contact with the air in order to avoid oxidisation, the specimen A presented exactly the same appearance as that shown in the next micro-photograph, that is, showed a ferrite and pearlite structure identical with specimen B.

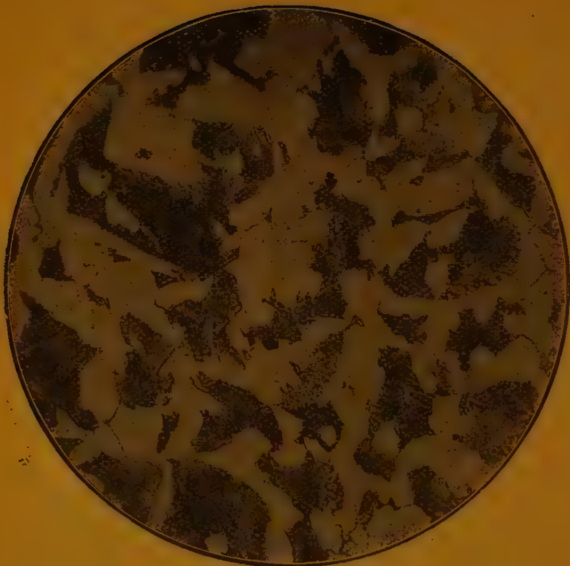


Fig. 58. — Specimen A after re-heating. — 400 ×

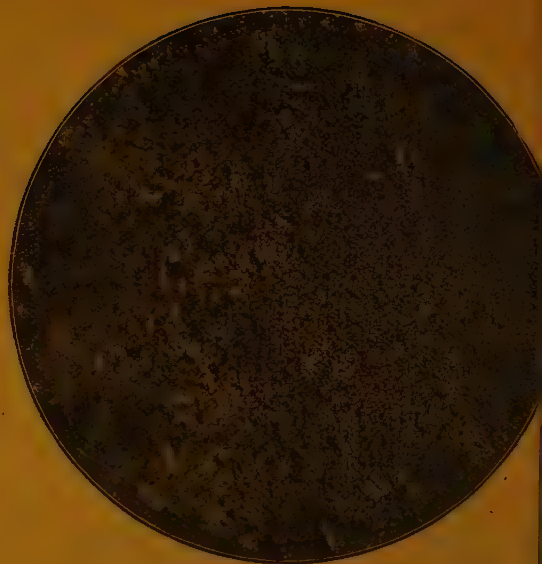


Fig. 60. — 400 ×

Specimens were taken at C, D, E and F with the object of ascertaining whether in the defective region, all the portions of the rail had become hardened.

Micrographic examination showed that there was hardening at C and D, while specimens E and F showed a normal structure (ferrite and pearlite).

It was only the head of the rail therefore which was hardened.

We show in figure 60 a photograph of the specimen C taken at *a*, a distance of 0.75 mm. (0.029 inch) from the surface in the sorbitic region.

To sum up, in the region of the cracks, the metal was sound, but the rail had been subjected to an accidental local hardening due probably to rain having penetrated through an opening in the roof of the shed in which the rails were laid out to cool.

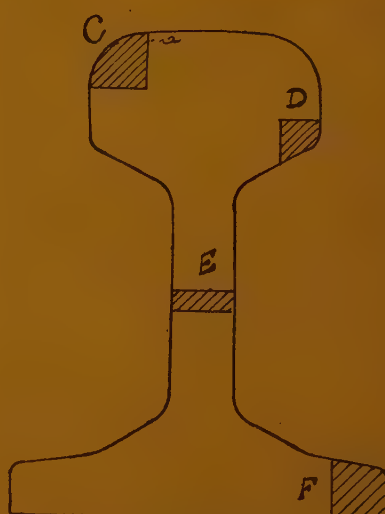



Fig. 59.

**2. Case of longitudinal cracks.**

During the year 1923, a certain number of 50 kgr. (100.79 lb. per yard) rails, which had been rolled in 1920 and 1921, developed defects and irregularities in service which necessitated their

being either taken out of the track or else kept under observation.

The first facts which were ascertained were as follows :

The defects for the most part appeared to commence on the upper surface of the rail, on the inner side, by a very localised spreading of the head of the rail, which showed the commencement of an interior longitudinal crack.

This spreading was accompanied by a partial sinking which had the effect of bringing the tyres of the vehicles to bear on another portion.

This defect gradually increased in depth and length under the combined action of the repeated shocks and the out of centre loading of the 50 kgr. (100.79 lb. per yard) rail with a head 72 mm. (2 53/64 inch) wide laid vertically.

Lastly, the portion of the head which carried the load broke away and finally became detached at a position vertically over the outside of the web over a length corresponding to the length of the crack (see figure 61). The subsequent observations which were made confirmed those made in the first place.

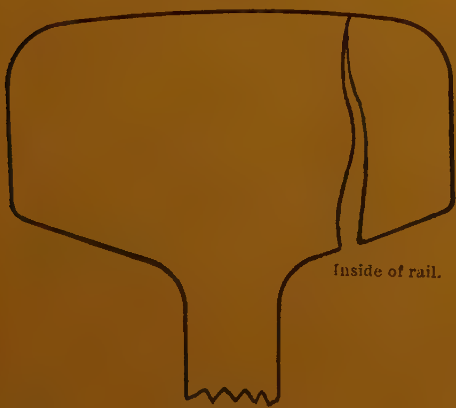



Fig 61.

These rails were taken up in order to be examined.

The facts which emerged after taking macrographs, micrographs and impact tests were as follows :

1. A piece taken from each rail to be tested was polished and etched with the Heyn reagent. Certain specimens showed signs of segregation in the web spreading out into the head and foot. Certain fractures had followed or extended into the lines formed by the regions of segregation.

Baumann prints showed regions of a high sulphur content (see figures 35 and 36);

2. Impact test pieces of a Mesnager type were machined from the head of a rail on either side of the crack taken in most cases from the position shown in figure 62. The results of these tests are

Fig. 62.

given below. *It is to be noticed that the figures representing brittleness are very low.* With rails of sound steel we generally obtain figures which range from 2.5 to 5 or even higher;

| Test pieces taken from cast numbers. | Section in millimetres. | Resilience or energy absorbed in causing fracture per square centimetre. | *Remarks.* |
|---|---|---|---|
| 158 | 10.1 × 8.0 | 0.717 | These tests were carried out with a Charpy falling weight of 30 kgrm. |
| 158 | 10.0 × 8.0 | 1.057 | |
| 167 | 10.0 × 8.0 | 1.231 | |
| 133 | 10.0 × 8.0 | 0.725 | |
| 133 | 10.1 × 8.0 | 0.879 | |
| 150 | 10.0 × 8.0 | 0.888 | |
| 150 | 10.0 × 8.0 | 1.408 | |
| 6 | 10.1 × 8.0 | 0.717 | |
| 1 | 10.1 × 8.0 | 0.563 | |
| 135 | 10.0 × 8.0 | 0.725 | |
| 135 | 10.0 × 8.0 | 0.725 | |
| 18 | 10.0 × 8.0 | 1.231 | |
| 18 | 10.1 × 8.0 | 2.350 | Jammed in testing machine |
| 108 | 10.0 × 8.0 | 1.231 | |

3. Micrographs of various specimens taken from the head of the rails explained their brittleness.

These specimens showed that the steel of which the rails were made was unsound and contained a number of very small blow holes and non-metallic inclusions which, under the repeated shocks and stresses set up in the parts under consideration, developed and finally joined up forming fractures. In some rails these cracks ran into a segregated region and have extended along the line of the impurities (1).

The various micrographs which have been chosen show very well the progressive development of the defects in the steel and of the lines of cracks which have arisen from the numerous non-metallic inclusions in the steel.

We also give micrographs which show that the cracks have followed the lines of the slag and non-metallic inclusions. It may be therefore concluded that the rails which have developed cracks were made from ingots or parts of ingots which were unsound, oxidised and segregated, and therefore of very inferior quality.

It should be noted that only macrographs and micrographs confirmed by impact tests are able to reveal the cause of premature defects in rails, and it is along these lines that investigations should be pursued in the future in accepting rails offered for delivery, seeing that the mechanical tests (tensile and falling weight) which are laid down in the specifications, although still of importance and utility, are not always capable of revealing defects in the metal, whereas the micrographs or macrographs can exactly show the position of the zones and lines of impurities which lead to the development of incipient cracks.

It may be remarked that the majority of rails which are found defective were made from the first casts which were rolled after the resumption of work in the steel works after the war. At the time when these rails were inspected, only the mechanical tests were carried out, and lack of homogenity due to segregation could not be detected, this being only visible by means of a macrographic or micrographic examination.

These micrographs show the large number of blow holes and non-metallic inclusions which destroyed the continuity of the steel. The two micrographs,

(1) Mr. Fremont in his memoir on the *Causes of premature wear of rails*, expresses an opinion in absolute conformity with our opinion as regards rails showing defects of this nature.

100 ×

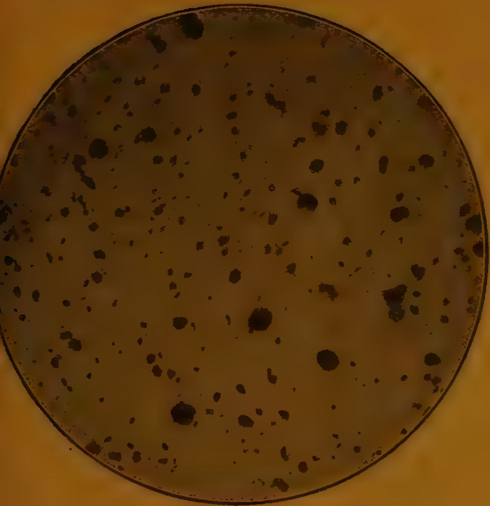


Fig. 63. — Micrograph No. 1 taken before etching and at right angles to the direction of rolling, the specimen being taken from the centre of the head of a rail from cast No. 6.

100 ×

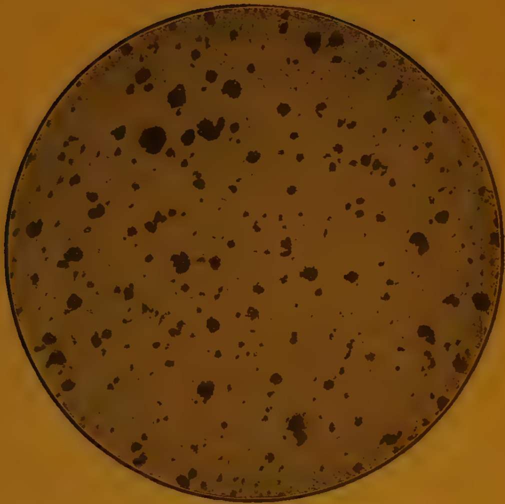


Fig. 64. — Micrograph No. 2 taken before etching and at right angles to the direction of rolling, the specimen being taken from the centre of the head of a rail from cast No. 167.

100 ×

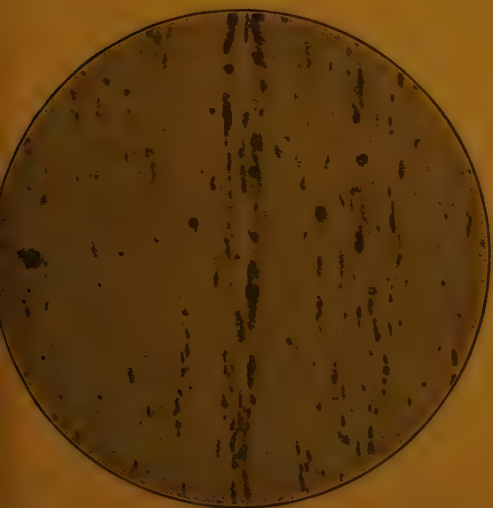


Fig. 65. — Micrograph No. 3 taken before etching from a specimen from the centre of the head of a rail from cast No. 133.

100 ×

Fig. 66. — Micrograph No. 4 taken before etching from a specimen from the centre of the head of a rail from cast No. 6.

Nos. 3 and 4, show the first stage of the development and the gradual joining up of the blow holes and inclusions in process of fissuring.

100 ×

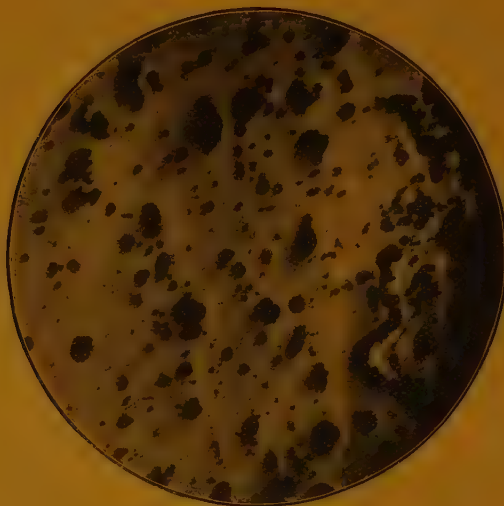


Fig. 67. — Micrograph No. 5 taken before etching from a specimen taken from one side of a crack in a rail from cast No. 133 showing that the fracture has developed along the line of blow holes and impurities.

### III. — Surface cracks.

The question of the formation of surface cracks on the upper surface of the rail resulting from the action of the rolling load and from superficial hardening, which is due especially to the slipping of wheels, has attracted our attention, but we have not up to the present found any case of rails breaking which may be directly attributed to this cause. We are continuing our observations with the object of determining the influence of this action.

**APPENDIX.**

BELGIAN STATE RAILWAYS.

PERMANENT WAY MATERIAL INSPECTION COMMITTEE.

## Report of acceptance No. ........

## RAILS.

Purchase approved ............................................ for the supply of ..............

........................................................................................................

........................................................................................................

........................................................................................................

........................................................................................................

........................................................................................................

Maker ............................................................................ Marks ..............................

Date when ready at the works ..............................................................................

Date of acceptance ..............................................................................................

Inspector responsible for the examination of material purchased :

Inspector's signature :

Brussels, ........................................, 192.....

*Particulars entered by the assistants interested.*

Approved :

*Inspector General,*
*President of the Inspection Committee.*

*N. B.* — In the present Specification, only one preliminary impact test per cast is laid down, because at the time these rails were made, the clause specifiing a test above the top portions of all ingots was not yet in existence.

The majority of the following tables are extracts intended to show the form in which the information is recorded.

## A. — Falling weight tests at the maker's works.

*Falling weight : 1 000 kgr. (2 200 lb.). — Distance between supports : 1.10 m. (3 ft. 7 5/16 in.).*

| Cast number. | Number of ingots. | Deflection after blow. From a height of 4 m. (13 ft. 1 1/2 in.) | | Deflection after blow. From a height of 6 m. (19 ft. 8 1/4 in.). 1st blow. | | Deflection after blow. From a height of 6 m. (19 ft. 8 1/4 in.). 2nd blow. | | Remarks. |
|---|---|---|---|---|---|---|---|---|
| | | Millim. | Inches. | Millim. | Inches. | Millim. | Inches. | |
| 1 T | 4 | 34 | 1 11/32 | 52 | 2 3/64 | 100 | 3 15/16 | |
| 1 C | | ... | ... | 53 | 2 3/32 | 99 | 3 57/64 | |
| 2 | 5 | 36 | 1 27/64 | ... | ... | ... | ... | |
| 3 | 5 | 38 | 1 1/2 | ... | ... | ... | ... | |
| 4 | 5 | 39 | 1 17/32 | ... | ... | ... | ... | |
| 5 | 4 | 35 | 1 3/8 | 54 | 2 1/8 | 105 | 4 9/64 | |
| 6 | 5 | 37 | 1 29/64 | ... | ... | ... | ... | |
| 7 | 4 | 39 | 1 17/32 | ... | ... | ... | ... | |
| 8 | 5 | 41 | 1 39/64 | ... | ... | ... | ... | |
| 9 | 5 | 43 | 1 11/16 | ... | ... | ... | ... | |
| 10 | 4 | 40 | 1 37/64 | ... | ... | ... | ... | |
| 11 | 3 | 38 | 1 1/2 | 57 | 2 1/4 | 107 | 4 13/64 | |
| 12 | 5 | 42 | 1 21/32 | ... | ... | ... | ... | |
| 13 | 5 | 41 | 1 39/64 | ... | ... | ... | ... | |
| 14 | 5 | 38 | 1 1/2 | ... | ... | ... | ... | |
| 15 | 5 | 37 | 1 29/64 | 55 | 2 11/64 | 105 | 4 9/64 | |
| 16 | 5 | 39 | 1 17/32 | ... | ... | ... | ... | |
| 17 | 5 | 36 | 1 27/64 | ... | ... | ... | ... | |
| 18 | 5 | 38 | 1 1/2 | ... | ... | ... | ... | |
| 19 | 5 | 42 | 1 21/32 | ... | ... | ... | ... | |
| 20 | 5 | 38 | 1 1/2 | ... | ... | ... | ... | |
| 21 | 5 | 36 | 1 27/64 | 52 | 2 3/64 | 101 | 3 63/64 | |
| 22 | 5 | 40 | 1 37/64 | ... | ... | ... | ... | |
| 23 | 5 | 39 | 1 17/32 | ... | ... | ... | ... | |
| 24 | 5 | 37 | 1 29/64 | ... | ... | ... | ... | |
| 25 | 5 | 41 | 1 39/64 | ... | ... | ... | ... | |
| 26 | 5 | 39 | 1 17/32 | ... | ... | ... | ... | |
| 27 | 5 | 37 | 1 29/64 | 55 | 2 11/64 | 105 | 4 9/64 | |
| 28 | 5 | 40 | 1 37/64 | ... | ... | ... | ... | |
| 29 | 5 | 43 | 1 11/16 | ... | ... | ... | ... | |
| 30 | 5 | 39 | 1 27/32 | ... | ... | ... | ... | |
| 31 | 5 | 38 | 1 1/2 | ... | ... | ... | ... | |
| 32 | 5 | 37 | 1 29/64 | ... | ... | ... | ... | |
| 33 T | 5 | 40 | 1 37/64 | 58 | 2 9/32 | 109 | 4 9/32 | |
| 33 C | | ... | ... | 59 | 2 21/64 | 109 | 4 9/32 | |
| 34 | 5 | 38 | 1 1/2 | ... | ... | ... | ... | |
| 35 | 5 | 41 | 1 39/64 | ... | ... | ... | ... | |
| 36 | 5 | 42 | 1 21/32 | 58 | 2 9/32 | 110 | 4 5/16 | |
| 37 | 5 | 38 | 1 1/2 | ... | ... | ... | ... | |
| 38 | 5 | 40 | 1 37/64 | ... | ... | ... | ... | |
| 39 | 5 | 37 | 1 29/64 | ... | ... | ... | ... | |
| 40 | 5 | 38 | 1 1/2 | ... | ... | ... | ... | |
| 41 | 5 | 36 | 1 27/64 | 52 | 2 3/64 | 99 | 3 57/64 | |
| 42 | 5 | 39 | 1 27/32 | ... | ... | ... | ... | |
| 43 | 5 | 37 | 1 29/64 | ... | ... | ... | ... | |
| 44 | 5 | 41 | 1 39/64 | ... | ... | ... | ... | |
| 45 | 4 | 40 | 1 37/64 | ... | ... | ... | ... | |
| 46 | 5 | 38 | 1 1/2 | ... | ... | ... | ... | |
| 47 | 5 | 35 | 1 3/8 | 53 | 2 3/32 | 101 | 3 63/64 | |
| 48 | 4 | 37 | 1 29/64 | ... | ... | ... | ... | |
| 49 | 4 | 40 | 1 37/64 | ... | ... | ... | ... | |
| 50 | 5 | 42 | 1 21/32 | ... | ... | ... | ... | |
| 51 | 5 | 40 | 1 37/64 | ... | ... | ... | ... | |
| 52 | 5 | 39 | 1 17/32 | 57 | 2 1/4 | 108 | 4 15/64 | |
| 53 | 5 | 43 | 1 11/16 | ... | ... | ... | ... | |
| 54 | 4 | 40 | 1 37/64 | ... | ... | ... | ... | |
| 55 | 5 | 38 | 1 1/2 | ... | ... | ... | ... | |
| 56 | 5 | 36 | 1 27/64 | 53 | 2 2/32 | 102 | 4 1/64 | |
| 57 | 5 | 39 | 1 17/32 | ... | ... | ... | ... | |
| 58 | 5 | 37 | 1 29/64 | ... | ... | ... | ... | |
| 59 | 5 | 40 | 1 37/64 | ... | ... | ... | ... | |
| 60 | 5 | 42 | 1 21/32 | ... | ... | ... | ... | |
| 61 | 5 | 41 | 1 39/64 | ... | ... | ... | ... | |
| 62 | 5 | 36 | 1 27/64 | 52 | 2 3/64 | 99 | 3 57/64 | |
| 63 | 5 | 38 | 1 1/2 | ... | ... | ... | ... | |
| 64 | 5 | 37 | 1 29/64 | ... | ... | ... | ... | |
| 65 | 5 | 39 | 1 17/32 | ... | ... | ... | ... | |
| 66 | 5 | 40 | 1 37/64 | 58 | 2 9/32 | 109 | 4 9/32 | |
| 67 | 5 | 42 | 1 21/32 | ... | ... | ... | ... | |
| 68 | 4 | 35 | 1 3/8 | 52 | 2 3/64 | 100 | 3 15/16 | |
| 69 | 5 | 38 | 1 1/2 | ... | ... | ... | ... | |
| 70 | 5 | 39 | 1 17/32 | ... | ... | ... | ... | |
| 71 | 5 | 37 | 1 29/64 | ... | ... | ... | ... | |
| 72 | 5 | 40 | 1 37/64 | ... | ... | ... | ... | |
| 73 | 5 | 38 | 1 1/2 | 55 | 2 11/64 | 106 | 4 15/64 | |
| 74 | 5 | 42 | 1 21/32 | ... | ... | ... | ... | |
| 75 | 4 | 39 | 1 17/32 | ... | ... | ... | ... | |
| 76 | 5 | 40 | 1 37/64 | ... | ... | ... | ... | |
| 77 | 5 | 41 | 1 39/64 | ... | ... | ... | ... | |
| 78 | 5 | 37 | 1 29/64 | 56 | 2 13/64 | 105 | 4 9/64 | |

T signifies : Head of ingot. — C. signifies : Bottom portion of ingot.

## A. — Falling weight tests at the maker's works. *(Continued.)*

*Falling weight : 1 000 kgr. (2 200 lb.). — Distance between supports : 1.10 m. (3 ft. 7 5/16 in.).*

| Cast number. | Number of ingots. | Deflection after blow. From a height of 4 m. (13 ft. 1 1/2 in.) Millim. | Inches. | From a height of 6 m. (19 ft. 8 1/4 in.). 1st blow. Millim. | Inches. | 2nd blow. Millim. | Inches. | Remarks. |
|---|---|---|---|---|---|---|---|---|
| 79 | 5 | 42 | 1 21/32 | ... | ... | ... | ... | |
| 80 | 5 | 40 | 1 37/64 | ... | ... | ... | ... | |
| 81 | 5 | 36 | 1 27/64 | ... | ... | ... | ... | |
| 82 | 5 | 38 | 1 1/2 | ... | ... | ... | ... | |
| 83 | 5 | 37 | 1 29/64 | 56 | 2 13/64 | 105 | 4 9/64 | |
| 84 | 5 | 39 | 1 17/32 | ... | ... | ... | ... | |
| 85 | 5 | 41 | 1 39/64 | ... | ... | ... | ... | |
| 86 | 5 | 40 | 1 37/64 | ... | ... | ... | ... | |
| 87 | 5 | 42 | 1 21/32 | ... | ... | ... | ... | |
| 88 | 5 | 38 | 1 1/2 | 54 | 2 1/8 | 104 | 4 5/64 | |
| 89 | 5 | 36 | 1 27/64 | ... | ... | ... | ... | |
| 90 | 5 | 39 | 1 17/32 | ... | ... | ... | ... | |
| 91 | 5 | 37 | 1 29/64 | ... | ... | ... | ... | |
| 92 | 5 | 35 | 1 3/8 | 52 | 2 3/64 | 99 | 3 57/64 | |
| 93 | 5 | 38 | 1 1/2 | ... | ... | ... | ... | |
| 94 | 5 | 40 | 1 37/64 | ... | ... | ... | ... | |
| 95 | 5 | 39 | 1 17/32 | ... | ... | ... | ... | |
| 96 | 5 | 41 | 1 39/64 | 58 | 2 9/32 | 109 | 4 9/32 | |
| 97 | 5 | 42 | 1 21/32 | ... | ... | ... | ... | |
| 98 | 3 | 37 | 1 29/64 | ... | ... | ... | ... | |
| 99 | 3 | 35 | 1 3/8 | ... | ... | ... | ... | |
| 100 | 4 | 38 | 1 1/2 | ... | ... | ... | ... | |
| 101 T | 5 | 40 | 1 37/64 | 59 | 2 21/64 | 110 | 4 5/16 | |
| 101 C | | ... | ... | 57 | 2 1/4 | 106 | 4 15/64 | |
| 102 | 5 | 36 | 1 27/64 | ... | ... | ... | ... | |
| 103 | 5 | 41 | 1 39/64 | ... | ... | ... | ... | |
| 104 | 5 | 36 | 1 27/64 | ... | ... | ... | ... | |
| 105 | 5 | 39 | 1 17/32 | ... | ... | ... | ... | |
| 106 | 5 | 37 | 1 29/64 | ... | ... | ... | ... | |
| 107 | 5 | 40 | 1 37/64 | ... | ... | ... | ... | |
| 108 | 5 | 35 | 1 3/8 | 53 | 2 3/32 | 101 | 3 63/64 | |
| 109 | 5 | 42 | 1 21/32 | ... | ... | ... | ... | |
| 110 | 5 | 41 | 1 39/64 | ... | ... | ... | ... | |
| 111 | 5 | 39 | 1 17/32 | ... | ... | ... | ... | |
| 112 | 5 | 40 | 1 37/64 | ... | ... | ... | ... | |
| 113 | 5 | 38 | 1 1/2 | 55 | 2 11/64 | 107 | 4 13/64 | |
| 114 | 5 | 42 | 1 21/32 | ... | ... | ... | ... | |
| 115 | 5 | 40 | 1 37/64 | ... | ... | ... | ... | |
| 116 | 4 | 39 | 1 17/32 | ... | ... | ... | ... | |
| 117 | 4 | 41 | 1 39/64 | ... | ... | ... | ... | |
| | 566 ingots. | | | | | | | |

T signifies ; Head of ingot. — C signifies : Bottom portion of ingot.

## B. — Falling weight tests at Malines Laboratory.

| Cast number. | Deflection after blow from a height of 6 m. (19 ft. 8 1/4 in.). 1st blow. | 2nd blow. | Remarks. |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

| Cast number | Deflection after blow from a height of 6 m. (19 ft. 8 1/4 in.). 1st blow. | 2nd blow. | Remarks. |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

## C. — Tensile tests at maker's works.

*Type of machine* . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

*Accepted by the railway administration* . . . . . . . . . . . . . . . . . . . . . .

| Cast number. | Diameter of test piece | | Cross area of test piece | | Elastic limit. | | | | Ultimate tensile strength | | | | Elongation | | | Reduction in area. | | | R+2A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | in millimetres. | in inches. | in square millimetres. | in square inches. | Total load in kilo-grammes. | Total load in lb. | Kilograms per square millimetre. | lb. per square inch. | total in kilo-grammes. | total in lb. | kgr. per square millimetre. | lb. per square inch. | total in milli-metres. | total in inches. | Per cent. | Final diameter in milli-metres. | Final diameter in inches. | $\frac{S-s}{S}\times 100$ | |
| 1 T | 16 | 0.630 | 201.1 | 0.312 | 9 400 | 20 720 | 46.7 | 66 420 | 15 500 | 34 170 | 77.1 | 109 660 | 27 | 1.063 | 13.5 | 13.2 | 0.520 | 32.0 | 104.1 |
| 1 C | 16 | 0.630 | 201.1 | 0.312 | 9 100 | 20 060 | 45.3 | 64 430 | 15 400 | 33 950 | 76.6 | 108 950 | 26 | 1.024 | 13.0 | 13.1 | 0.516 | 33.0 | 102.6 |
| 5 T | 16 | 0.630 | 201.1 | 0.312 | 9 200 | 20 280 | 45.8 | 65 140 | 15 300 | 33 730 | 76.1 | 108 230 | 25 | 0.984 | 12.5 | 13.4 | 0.528 | 29.9 | 101.1 |
| 11 T | 16 | 0.630 | 201.1 | 0.312 | 9 400 | 20 720 | 46.7 | 66 420 | 15 300 | 33 730 | 76.1 | 108 230 | 29 | 1.142 | 14.5 | 12.9 | 0.508 | 35.0 | 105.1 |
| 15 T | 16 | 0.630 | 201.1 | 0.312 | 9 000 | 19 840 | 44.8 | 63 720 | 15 300 | 33 730 | 76.1 | 108 230 | 26 | 1.024 | 13.0 | 13.3 | 0.524 | 30.9 | 102.1 |
| 21 T | 16 | 0.630 | 201.1 | 0.312 | 9 100 | 20 060 | 45.3 | 64 430 | 15 400 | 33 950 | 76.6 | 108 950 | 26 | 1.024 | 13.0 | 12.8 | 0.504 | 36.0 | 102.6 |
| 27 T | 16 | 0.630 | 201.1 | 0.312 | 9 000 | 19 840 | 44.8 | 63 720 | 15 200 | 33 510 | 75.6 | 107 520 | 28 | 1.102 | 14.0 | 12.7 | 0.500 | 37.0 | 103.6 |
| 33 T | 16 | 0.630 | 201.1 | 0.312 | 8 900 | 19 620 | 44.3 | 63 010 | 15 000 | 33 070 | 74.6 | 106 100 | 30 | 1.181 | 15.0 | 12.6 | 0.496 | 38.0 | 104.6 |
| 33 C | 16 | 0 630 | 201.1 | 0.312 | 9 300 | 20 500 | 46.2 | 65 710 | 15 400 | 33 950 | 76.6 | 108 950 | 28 | 1.102 | 14.0 | 12.8 | 0.504 | 36.0 | 104.6 |
| 36 T | 16 | 0.630 | 201.1 | 0.312 | 9 000 | 19 840 | 44.8 | 63 720 | 15 200 | 33 510 | 75.6 | 107 520 | 30 | 1.181 | 15.0 | 12.9 | 0.508 | 35.0 | 105.6 |
| 41 T | 16 | 0.630 | 201.1 | 0.312 | 9 000 | 19 840 | 44.8 | 63 720 | 15 100 | 33 290 | 75.1 | 106 810 | 30 | 1.181 | 15.0 | 12.8 | 0.504 | 36.0 | 105.1 |
| 47 T | 16 | 0.630 | 201.1 | 0.312 | 8 000 | 17 640 | 39.8 | 56 610 | 14 400 | 31 740 | 71.6 | 111 830 | 29 | 1.142 | 14.5 | 12.5 | 0.492 | 39.0 | 100.6 |
| 52 T | 16 | 0.630 | 201.1 | 0.312 | 8 300 | 18 300 | 41.3 | 58 740 | 14 700 | 32 410 | 73.1 | 103 970 | 32 | 1.260 | 16.0 | 12.6 | 0.496 | 38.0 | 105.1 |
| 56 T | 16 | 0.630 | 201.1 | 0.312 | 8 800 | 19 400 | 43.8 | 62 300 | 15 500 | 34 170 | 77.1 | 109 660 | 25 | 0.984 | 12.5 | 13.4 | 0.528 | 29.9 | 102.1 |
| 62 T | 16 | 0.630 | 201.1 | 0.312 | 9 400 | 20 720 | 46.7 | 66 420 | 15 700 | 34 610 | 78.1 | 111 080 | 26 | 1.024 | 13.0 | 12.9 | 0 508 | 35.0 | 104.1 |
| 66 T | 16 | 0.630 | 201.1 | 0.312 | 8 900 | 19 620 | 44.3 | 63 010 | 15 300 | 33 730 | 76.1 | 108 230 | 27 | 1.063 | 13.5 | 13.0 | 0.512 | 34.0 | 103.1 |
| 68 T | 15.95 | 0.628 | 200.0 | 0.310 | 9 100 | 20 060 | 45.3 | 64 430 | 15 200 | 33 510 | 76.0 | 108 090 | 29 | 1.142 | 14.5 | 12.7 | 0.500 | 36.6 | 105.0 |
| 73 T | 16 | 0.630 | 201.1 | 0.312 | 8 100 | 17 860 | 40.3 | 57 320 | 14 600 | 32 190 | 72.6 | 103 260 | 27 | 1.063 | 13.5 | 12.8 | 0.504 | 36.0 | 99.6 |
| 78 T | 15.95 | 0.628 | 200.0 | 0.310 | 9 300 | 20 500 | 46.5 | 66 130 | 15 400 | 33 950 | 77.0 | 109 510 | 29 | 1.142 | 14.5 | 12.9 | 0.508 | 34.6 | 106.0 |
| 83 T | 16 | 0.630 | 201.1 | 0.312 | 9 400 | 20 720 | 46.7 | 66 420 | 15 600 | 34 390 | 77.6 | 110 370 | 29 | 1 142 | 14.5 | 12.7 | 0.500 | 37.0 | 106.6 |
| 88 T | 15.95 | 0.628 | 200.0 | 0.310 | 9 000 | 19 840 | 45.0 | 64 000 | 15 000 | 33 070 | 75.0 | 106 670 | 32 | 1.260 | 16.0 | 13.1 | 0.516 | 32.5 | 107.0 |
| 92 T | 15.85 | 0.624 | 197.0 | 0.306 | 8 900 | 19 620 | 45.1 | 64 140 | 15 200 | 33 510 | 77.0 | 109 510 | 31 | 1 220 | 15.5 | 13.3 | 0.524 | 29.6 | 108.0 |
| 96 T | 16 | 0.630 | 201.1 | 0.312 | 9 000 | 19 840 | 44.8 | 63 720 | 14 800 | 32 630 | 73.6 | 104 680 | 30 | 1.181 | 15.0 | 12.6 | 0.496 | 38.0 | 103.6 |
| 101 T | 16 | 0.630 | 201.1 | 0.312 | 9 200 | 20 280 | 45.8 | 65 140 | 15 100 | 33 290 | 75.1 | 106 810 | 29 | 1.142 | 14.5 | 12.7 | 0.500 | 37.0 | 104.1 |
| 101 C | 16 | 0.630 | 201.1 | 0.312 | 9 300 | 20 500 | 46.2 | 65 710 | 15 000 | 33 070 | 74.6 | 106 100 | 31 | 1.220 | 15.5 | 12.7 | 0.500 | 37.0 | 105.6 |
| 108 T | 16 | 0.630 | 201.1 | 0.312 | 9 200 | 20 280 | 45.8 | 65 140 | 15 500 | 34 170 | 77.1 | 109 660 | 29 | 1.142 | 14.5 | 13.0 | 0.512 | 34.0 | 106.1 |
| 113 T | 16 | 0.630 | 201.1 | 0.312 | 9 000 | 19 840 | 44.8 | 63 720 | 15 200 | 33 510 | 75.6 | 107 520 | 28 | 1.102 | 14.0 | 12.9 | 0.508 | 35.0 | 103.6 |

D. — **Tensile tests carried out at Malines Laboratory.**

| Cast number. | Diameter of test piece, in millimetres. | Cross area of test piece, in square millimetres. | Elastic limit. | | Ultimate tensile strength | | Elongation | | Reduction in area. | | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Total load. | Kilogrammes per square millimetre. | total. | per square millimetres. | total. | % | Final diameter. | $\frac{S - s}{S} \times 100$ | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |
| | | | | | | | | | | | |

E. — **Bending tests carried out at the maker's works and at Malines Laboratory.**

*Permanent deflection after a load of 35 t.*

*Applied for five minutes.*

*Distance between supports 1 m. 10 (3 ft. 7 5/16 in.).*

| Cast number. | At maker's works. |
|---|---|
| 36 T | Deflection under load = 4.5 mm. (0.177 inch); fl. p. = 0 |
| 66 T | Deflection under load = 4.25 mm. (0.166 inch); fl. p. = 0 |
| | fl. p. = Permanent deflection. |

| Cast number. | At Malines Laboratory. |
|---|---|
| | |
| | |
| | |
| | |
| | |

F. — **Chemical analysis at Malines Laboratory.**

| Cast number. | S % | Ph % | Si % | C % | Mn % |
|---|---|---|---|---|---|
| 5 T . . . . | 0.044 | 0.065 | 0.167 | 0.45 | 0.93 |
| 36 T . . . . | 0.058 | 0.070 | 0.179 | 0.42 | 0.98 |
| 66 T . . . . | 0.054 | 0.068 | 0.169 | 0.41 | 0.95 |
| | | | | | |

## G. — Chemical analysis at maker's works.

| Cast number. | S. | Ph. | Si. | C. | Mn. |
|---|---|---|---|---|---|
| 1 | 0.047 | 0.060 | 0.17 | 0.45 | 0.90 |
| 2 | 0.050 | 0.065 | 0.17 | 0.45 | 0.90 |
| 3 | 0.052 | 0.070 | 0.14 | 0.44 | 0.95 |
| 4 | 0.047 | 0.068 | 0.13 | 0.45 | 0.95 |
| 5 | 0.047 | 0.065 | 0.14 | 0.43 | 0.95 |
| 6 | 0.045 | 0.069 | 0.16 | 0.46 | 0.85 |
| 7 | 0.045 | 0.072 | 0.14 | 0.44 | 0.95 |
| 8 | 0.052 | 0.067 | 0.15 | 0.42 | 0.95 |
| 9 | 0.049 | 0.062 | 0.13 | 0.42 | 1.00 |
| 10 | 0.053 | 0.069 | 0.13 | 0.41 | 1.00 |
| 11 | 0.054 | 0.071 | 0.14 | 0.46 | 0.90 |
| 12 | 0.042 | 0.067 | 0.13 | 0.44 | 0.95 |
| 13 | 0.050 | 0.060 | 0.14 | 0.43 | 1.00 |
| 14 | 0.046 | 0.060 | 0.15 | 0.46 | 0.90 |
| 15 | 0.054 | 0.063 | 0.13 | 0.45 | 0.95 |
| 16 | 0.050 | 0.064 | 0.14 | 0.45 | 0.95 |
| 17 | 0.048 | 0.066 | 0.14 | 0.42 | 1.00 |
| 18 | 0.055 | 0.070 | 0.14 | 0.43 | 0.95 |
| 19 | 0.048 | 0.064 | 0.15 | 0.46 | 0.85 |
| 20 | 0.056 | 0.062 | 0.17 | 0.43 | 0.90 |
| 21 | 0.051 | 0.060 | 0.15 | 0.42 | 0.95 |
| 22 | 0.047 | 0.062 | 0.13 | 0.45 | 0.95 |
| 23 | 0.046 | 0.059 | 0.13 | 0.43 | 0.95 |
| 24 | 0.054 | 0.067 | 0.13 | 0.43 | 1.00 |
| 25 | 0.050 | 0.065 | 0.14 | 0.46 | 0.90 |
| 26 | 0.050 | 0.070 | 0.15 | 0.46 | 0.85 |
| 27 | 0.052 | 0.068 | 0.16 | 0.45 | 0.90 |
| 28 | 0.048 | 0.072 | 0.14 | 0.43 | 0.95 |
| 29 | 0.045 | 0.064 | 0.14 | 0.42 | 1.00 |
| 30 | 0.051 | 0.066 | 0.15 | 0.45 | 0.90 |
| 31 | 0.049 | 0.063 | 0.14 | 0.45 | 0.95 |
| 32 | 0.054 | 0.069 | 0.13 | 0.45 | 0.90 |
| 33 | 0.057 | 0.062 | 0.14 | 0.44 | 0.95 |
| 34 | 0.048 | 0.060 | 0.13 | 0.45 | 0.95 |
| 35 | 0.043 | 0.063 | 0.15 | 0.46 | 0.90 |
| 36 | 0.056 | 0.073 | 0.14 | 0.45 | 0.90 |
| 37 | 0.050 | 0.068 | 0.13 | 0.43 | 0.95 |
| 38 | 0.047 | 0.059 | 0.14 | 0.44 | 1.00 |
| 39 | 0.052 | 0.061 | 0.15 | 0.43 | 0.95 |
| 40 | 0.054 | 0.060 | 0.15 | 0.41 | 1.00 |
| 41 | 0.046 | 0.062 | 0.15 | 0.43 | 0.90 |
| 42 | 0.045 | 0.060 | 0.13 | 0.45 | 1.00 |
| 43 | 0.043 | 0.060 | 0.14 | 0.46 | 0.95 |
| 44 | 0.048 | 0.064 | 0.13 | 0.42 | 0.95 |
| 45 | 0.050 | 0.067 | 0.13 | 0.46 | 0.90 |
| 46 | 0.050 | 0.070 | 0.13 | 0.44 | 0.95 |
| 47 | 0.047 | 0.068 | 0.15 | 0.46 | 0.85 |
| 48 | 0.053 | 0.062 | 0.16 | 0.42 | 0.90 |
| 49 | 0.050 | 0.067 | 0.14 | 0.44 | 0.90 |
| 50 | 0.050 | 0.063 | 0.15 | 0.42 | 0.95 |
| 51 | 0.044 | 0.065 | 0.15 | 0.44 | 0.95 |
| 52 | 0.050 | 0.062 | 0.14 | 0.44 | 0.95 |
| 53 | 0.046 | 0.064 | 0.15 | 0.46 | 0.90 |
| 54 | 0.045 | 0.060 | 0.16 | 0.46 | 0.90 |
| 55 | 0.051 | 0.067 | 0.16 | 0.45 | 0.90 |
| 56 | 0.052 | 0.064 | 0.14 | 0.41 | 1.00 |
| 57 | 0.048 | 0.059 | 0.13 | 0.43 | 1.00 |
| 58 | 0.050 | 0.065 | 0.14 | 0.45 | 0.95 |
| 59 | 0.055 | 0.070 | 0.15 | 0.46 | 0.90 |
| 60 | 0.052 | 0.061 | 0.15 | 0.45 | 0.95 |

G. — **Chemical analysis at maker's works.** (*Continued.*)

| Cast number. | S. | Ph. | Si. | C. | Mn. |
|---|---|---|---|---|---|
| 61 | 0.014 | 0.066 | 0.14 | 0 46 | 0.85 |
| 62 | 0.050 | 0.060 | 0.13 | 0.44 | 0.95 |
| 63 | 0.050 | 0.060 | 0.14 | 0.42 | 0.95 |
| 64 | 0.055 | 0.066 | 0.15 | 0.46 | 0.90 |
| 65 | 0.054 | 0.069 | 0.15 | 0.44 | 0.90 |
| 66 | 0.050 | 0.064 | 0.16 | 0.43 | 0.95 |
| 67 | 0.046 | 0.070 | 0.16 | 0 45 | 0.85 |
| 68 | 0.048 | 0.064 | 0.15 | 0.42 | 0.95 |
| 69 | 0.051 | 0.067 | 0.16 | 0.43 | 0.95 |
| 70 | 0.055 | 0.062 | 0.15 | 0.45 | 0.90 |
| 71 | 0.058 | 0.060 | 0.13 | 0.42 | 1.00 |
| 72 | 0.047 | 0.068 | 0.13 | 0.43 | 0.95 |
| 73 | 0.047 | 0.065 | 0.15 | 0.45 | 0.90 |
| 74 | 0.053 | 0.060 | 0.14 | 0.42 | 1.00 |
| 75 | 0.056 | 0.064 | 0.16 | 0.45 | 0.90 |
| 76 | 0 050 | 0.068 | 0 15 | 0.43 | 0.95 |
| 77 | 0.050 | 0.060 | 0.16 | 0.44 | 0.95 |
| 78 | 0.048 | 0.067 | 0.16 | 0.46 | 0.85 |
| 79 | 0.053 | 0.070 | 0.15 | 0.43 | 0.90 |
| 80 | 0.051 | 0 064 | 0.17 | 0.46 | 0.90 |
| 81 | 0.046 | 0.062 | 0.15 | 0.43 | 0 95 |
| 82 | 0.056 | 0.070 | 0.14 | 0.46 | 0.90 |
| 83 | 0.051 | 0.065 | 0.14 | 0 45 | 0.90 |
| 84 | 0.048 | 0.060 | 0.13 | 0.45 | 0.95 |
| 85 | 0.053 | 0.058 | 0.14 | 0.45 | 0.95 |
| 86 | 0.046 | 0.064 | 0.16 | 0.43 | 0.95 |
| 87 | 0.054 | 0.067 | 0.14 | 0.46 | 0.85 |
| 88 | 0.050 | 0.062 | 0.13 | 0.41 | 1.00 |
| 89 | 0.056 | 0.070 | 0.14 | 0.44 | 0.90 |
| 90 | 0.049 | 0.064 | 0.14 | 0.46 | 0.90 |
| 91 | 0.053 | 0.070 | 0.15 | 0.45 | 0.95 |
| 92 | 0.045 | 0.063 | 0.15 | 0.42 | 1.00 |
| 93 | 0.049 | 0.068 | 0.15 | 0.45 | 0.90 |
| 94 | 0.047 | 0.060 | 0.14 | 0.41 | 1 00 |
| 95 | 0.045 | 0.062 | 0.14 | 0.43 | 0.95 |
| 96 | 0.050 | 0.067 | 0.14 | 0.45 | 0.85 |
| 97 | 0.047 | 0.059 | 0.13 | 0.46 | 0.90 |
| 98 | 0.051 | 0.063 | 0.13 | 0.43 | 1.00 |
| 99 | 0.048 | 0.062 | 0.15 | 0.41 | 1.00 |
| 100 | 0.054 | 0.065 | 0.15 | 0.45 | 0.95 |
| 101 | 0.056 | 0.070 | 0.14 | 0.46 | 0.85 |
| 102 | 0.054 | 0.062 | 0.15 | 0.42 | 0.95 |
| 103 | 0.051 | 0.060 | 0.15 | 0.44 | 0.95 |
| 104 | 0.050 | 0.070 | 0.14 | 0.41 | 1.00 |
| 105 | 0.045 | 0.063 | 0.13 | 0.44 | 0.95 |
| 106 | 0.051 | 0.061 | 0.14 | 0.46 | 0.90 |
| 107 | 0.050 | 0.069 | 0.15 | 0.46 | 0.85 |
| 108 | 0.046 | 0.067 | 0.16 | 0.45 | 0.95 |
| 109 | 0.054 | 0.063 | 0.15 | 0.43 | 0.95 |
| 110 | 0.051 | 0.068 | 0.16 | 0.45 | 0.90 |
| 111 | 0.055 | 0.066 | 0.14 | 0.42 | 0.95 |
| 112 | 0.047 | 0.060 | 0.13 | 0.43 | 1.00 |
| 113 | 0.045 | 0.060 | 0.14 | 0.46 | 0.85 |
| 114 | 0.048 | 0.062 | 0.15 | 0.44 | 0.95 |
| 115 | 0.050 | 0.068 | 0.14 | 0.46 | 0.90 |
| 116 | 0.055 | 0.071 | 0.16 | 0.42 | 0.95 |
| 117 | 0.053 | 0.068 | 0.15 | 0.44 | 0.90 |

## H. — Impact tests at makers's works.

| Number of test. | Portion from which test pieces were taken. | Marks on test pieces. | Section exposed to shock. | Angle through which falling weight travels. | Energy absorbed. | Resilience or energy absorbed by fracture per square centimetre. | *Remarks.* |
|---|---|---|---|---|---|---|---|
| 1 T | Head . . . . | | 8 × 10 | 137 | 2.546 | 3.18 | These tests were carried out with a Charpy 30 kgrm. falling weight. |
| | Web . . . . | | 8 × 10 | 136 | 2.736 | 3.42 | |
| | Foot . . . . | | 8 × 10 | 139 | 2.176 | 2.72 | |
| 1 C | Head . . . . | | 8 × 10 | 140 | 1.996 | 2.48 | |
| | Web . . . . | | 8 × 10 | 141 | 1.820 | 2.27 | |
| | Foot . . . . | | 8 × 10 | 139 | 2.176 | 2.72 | |
| 5 T | Head . . . . | | 8 × 10 | 138 | 2.354 | 2.95 | |
| | Web . . . . | | 8 × 10 | 138 | 2.359 | 2.95 | |
| | Foot . . . . | | 8 × 10 | 139 | 2.176 | 2.72 | |
| 11 T | Head . . . . | | 8 × 10 | 135 | 2.930 | 3.69 | |
| | Web . . . . | | 8 × 10 | 135 | 2.930 | 3.69 | |
| | Foot . . . . | | 8 × 10 | 136 | 2.736 | 3.42 | |
| 15 T | Head . . . . | | 8 × 10 | 137 | 2.546 | 3.18 | |
| | Web . . . . | | 8 × 10 | 136 | 2.736 | 3.42 | |
| | Foot . . . . | | 8 × 10 | 138 | 2.359 | 2.95 | |
| 21 T | Head . . . . | | 8 × 10 | 140 | 1.996 | 2.48 | |
| | Web . . . . | | 8 × 10 | 138 | 2.359 | 2.95 | |
| | Foot . . . . | | 8 × 10 | 138 | 2.359 | 2.95 | |
| 27 T | Head . . . . | | 8 × 10 | 137 | 2.546 | 3.18 | |
| | Web . . . . | | 8 × 10 | 138 | 2.359 | 2.95 | |
| | Foot . . . . | | 8 × 10 | 136 | 2.736 | 3.42 | |
| 33 T | Head . . . . | | 8 × 10 | 138 | 2.359 | 2.95 | |
| | Web . . . . | | 8 × 10 | 135 | 2.930 | 3.69 | |
| | Foot . . . . | | 8 × 10 | 128 | 4.379 | 5.47 | Bent without breaking. |
| 33 C | Head . . . . | | 8 × 10 | 137 | 2.546 | 3.18 | |
| | Web . . . . | | 8 × 10 | 136 | 2.736 | 3.42 | |
| | Foot . . . . | | 8 × 10 | 137 | 2.546 | 3.18 | |
| 36 T | Head . . . . | | 8 × 10 | 135 | 2.930 | 3.69 | |
| | Web . . . . | | 8 × 10 | 135 | 2.930 | 3.69 | |
| | Foot . . . . | | 8 × 10 | 136 | 2.736 | 3.42 | |
| 41 T | Head . . . . | | 8 × 10 | 139 | 2.176 | 2.72 | |
| | Web . . . . | | 8 × 10 | 137 | 2.546 | 3.18 | |
| | Foot . . . . | | 8 × 10 | 140 | 1.996 | 2.48 | |
| 47 T | Head . . . . | | 8 × 10 | 140 | 1.996 | 2.48 | |
| | Web . . . . | | 8 × 10 | 137 | 2.546 | 3.18 | |
| | Foot . . . . | | 8 × 10 | 137 | 2.546 | 3.18 | |
| 52 T | Head . . . . | | 8 × 10 | 134 | 3.127 | 3.91 | |
| | Web . . . . | | 8 × 10 | 136 | 2.736 | 3.42 | |
| | Foot . . . . | | 8 × 10 | 136 | 2.736 | 3.42 | |
| 56 T | Head . . . . | | 8 × 10 | 140 | 1.996 | 2.48 | |
| | Web . . . . | | 8 × 10 | 141 | 1.820 | 2.27 | |
| | Foot . . . . | | 8 × 10 | 142 | 1.647 | 2.06 | |

H. — **Impact test at maker's works.** (*Continued.*)

| Number of test. | Portion from which test pieces were taken. | Marks on test pieces. | Section exposed to shock. | Angle through which falling weight travels. | Energy absorbed. | Resilience or energy absorbed by fracture per square centimetre | *Remarks.* |
|---|---|---|---|---|---|---|---|
| 62 T | Head . . . . | | 8 × 10 | 140 | 1.996 | 2.48 | |
| | Web . . . . | | 8 × 10 | 138 | 2.359 | 2.95 | |
| | Foot . . . . | | 8 × 10 | 140 | 1.996 | 2.48 | |
| 66 T | Head . . . . | | 8 × 10 | 135 | 2.930 | 3.69 | |
| | Web . . . . | | 8 × 10 | 135 | 2.930 | 3.69 | |
| | Foot . . . . | | 8 × 10 | 136 | 2.736 | 3.42 | |
| 68 T | Head . . . . | | 8 × 10 | 141 | 1.820 | 2.27 | |
| | Web . . . . | | 8 × 10 | 138 | 2.359 | 2.95 | |
| | Foot . . . . | | 8 × 10 | 138 | 2.359 | 2.95 | |
| 73 T | Head . . . . | | 8 × 10 | 140 | 1.996 | 2.48 | |
| | Web . . . . | | 8 × 10 | 136 | 2.736 | 3.42 | |
| | Foot . . . . | | 8 × 10 | 134 | 3.127 | 3.91 | |
| 78 T | Head . . . . | | 8 × 10 | 137 | 2.546 | 3.18 | |
| | Web . . . . | | 8 × 10 | 135 | 2.930 | 3.69 | |
| | Foot . . . . | | 8 × 10 | 138 | 2.359 | 2.95 | |
| 83 T | Head . . . . | | 8 × 10 | 136 | 2.736 | 3.42 | |
| | Web . . . . | | 8 × 10 | 135 | 2.930 | 3.69 | |
| | Foot . . . . | | 8 × 10 | 136 | 2.736 | 3.42 | |
| 88 T | Head . . . . | | 8 × 10 | 132 | 3.522 | 4.41 | Bent without breaking. |
| | Web . . . . | | 8 × 10 | 138 | 2.359 | 2.95 | |
| | Foot . . . . | | 8 × 10 | 134 | 3.127 | 3.91 | |
| 92 T | Head . . . . | | 8 × 10 | 139 | 2.171 | 2.72 | |
| | Web . . . . | | 8 × 10 | 137 | 2.546 | 3.18 | |
| | Foot . . . . | | 8 × 10 | 137 | 2.546 | 3.18 | |
| 96 T | Head . . . . | | 8 × 10 | 137 | 2.546 | 3.18 | |
| | Web . . . . | | 8 × 10 | 136 | 2.736 | 3.42 | |
| | Foot . . . . | | 8 × 10 | 135 | 2.930 | 3.69 | |
| 101 T | Head . . . . | | 8 × 10 | 134 | 3.127 | 3.91 | |
| | Web . . . . | | 8 × 10 | 135 | 2.930 | 3.69 | |
| | Foot . . . . | | 8 × 10 | 135 | 2.930 | 3.69 | |
| 101 C | Head . . . . | | 8 × 10 | 135 | 2.930 | 3.69 | |
| | Web . . . . | | 8 × 10 | 135 | 2.930 | 3.69 | |
| | Foot . . . . | | 8 × 10 | 138 | 2.359 | 2.95 | |
| 108 T | Head . . . . | | 8 × 10 | 140 | 1.996 | 2.48 | |
| | Web . . . . | | 8 × 10 | 137 | 2.546 | 3.18 | |
| | Foot . . . . | | 8 × 10 | 137 | 2.546 | 3.18 | |
| 113 T | Head . . . . | | 8 × 10 | 136 | 2.736 | 3.42 | |
| | Web . . . . | | 8 × 10 | 135 | 2.930 | 3.69 | |
| | Foot . . . . | | 8 × 10 | 135 | 2.930 | 3.69 | |
| ....... | Head . . . . | | — | — | — | — | |
| | Web . . . . | | — | — | — | — | |
| | Foot . . . . | | — | — | — | — | |

J. — **Macrographs.**

| Cast number. | RESULTS OBTAINED. |
|---|---|
| 1 T . . . . . . . . . | No trace of segregation. |
| 5 T . . . . . . . . . | |
| 11 T . . . . . . . . . | |
| 15 T . . . . . . . . . | |
| 21 T . . . . . . . . . | |
| 27 T . . . . . . . . . | |
| 33 T . . . . . . . . . | |
| 36 T . . . . . . . . . | |
| 41 T . . . . . . . . . | |
| 47 T . . . . . . . . . | |
| 52 T . . . . . . . . . | |
| 56 T . . . . . . . . . | |
| 62 T . . . . . . . . . | |
| 66 T . . . . . . . . . | |
| 68 T . . . . . . . . . | |
| 73 T . . . . . . . . . | |
| 78 T . . . . . . . . . | |
| 83 T . . . . . . . . . | |
| 88 T . . . . . . . . . | |
| 92 T . . . . . . . . . | |
| 96 T . . . . . . . . . | |

J. — **Macrographs.** (*Continued.*)

| Cast number. | RESULTS OBTAINED. |
|---|---|
| 101 T . . . . . . . . . | No trace of segregation. |
| 108 T . . . . . . . . . | |
| 113 T . . . . . . . . . | |
| *Additional sections.* | |
| 3 T *5th* ingot . . . | No trace of segregation. |
| 18 T *1st* ingot . . . | |
| 31 T *3d* ingot . . . | |
| 44 T *4th* ingot . . . | |
| 60 T *5th* ingot . . . | |
| 76 T *5th* ingot . . . | |
| 93 T *3d* ingot . . . | |
| 117 T *4th* ingot . . . | |

K. — **Micrographs.**

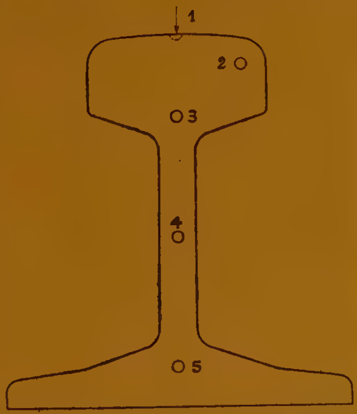
| Cast number. | RESULTS OBTAINED. |
|---|---|
| | |
| | |
| | |
| | |

L. — **Average weight per metre of rail,**
**calculated by weighing fifty rails of 18 m. (59 ft. 11/16 in.) length.**

**50.011 kgr. (110.253 lb. per yard).**

### I. — Impression of Brinell ball 10 mm. (3/8 inch) diameter under a pressure of 3 000 kgr. (6 600 lb.).

| Number of test. | Impression. | Corresponding Brinell number. | *Remarks.* |
|---|---|---|---|
| 36 T | 1... 4.30 mm. (0.1692 inch). | 197 | |
| | 2 .. 4 00 — (0.1575 — ). | 229 | |
| | 3... 4.00 — (0.1575 — ). | 229 | |
| | 4... 3.90 — (0.1535 — ). | 241 | |
| | 5... 4.05 — (0.1593 — ). | 223 | |
| 66 T | 1... 4.40 — (0.1732 — ). | 187 | |
| | 2 .. 4.15 — (0.1632 — ). | 212 | |
| | 3... 4.00 — (0.1575 — ). | 229 | |
| | 4... 4.10 — (0.1614 — ). | 217 | |
| | 5... 4.15 — (0.1632 — ). | 212 | |




### M. — Description of rails submitted for acceptance.

| CLASSIFICATION BY LENGTH AND ARRANGEMENT OF BOLT HOLES. | Quantities. Offered. | Quantities. Accepted. | Quantities. Rejected. | Total length, in metres. | Price per rail. | Partial sums. | *Remarks.* |
|---|---|---|---|---|---|---|---|
| 18 m. (59 ft. 11/16 in.) rails drilled at both ends and at centre. . | 1 142 | 1 142 | ... | 20 556.00 m. | | | |
| 17.88 m. (58 ft. 15/16 in.) rails drilled at both ends and at centre. . | 8 | 8 | ... | 143.04 m. | | | |
| | | | | 20 699.04 m. | | | |
| | | | | at 50.011 kgr. | | | |
| | | | | 1 035.180 t. | | | |

N. — **Record of the number of rails of various lengths from each cast.**

| Cast number. | NUMBER OF RAILS: | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 18.000 m. | | 17.88 m. | | 18.000 m. | | 17.88 m. | | 18.000 m. | | 17.88 m. | | 18.000 m. | | 17.88 m. | |
| | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. |
| 1 | 3 | 2 | | | | | | | | | | | | | | |
| 2 | 4 | 4 | | | | | | | | | | | | | | |
| 3 | 4 | 3 | | | | | | | | | | | | | | |
| 4 | 6 | 4 | | | | | | | | | | | | | | |
| 5 | 5 | 2 | | | | | | | | | | | | | | |
| 6 | 7 | 2 | | | | | | | | | | | | | | |
| 7 | 6 | 3 | | | | | | | | | | | | | | |
| 8 | 5 | 3 | | | | | | | | | | | | | | |
| 9 | 5 | 4 | | | | | | | | | | | | | | |
| 10 | 4 | 5 | | | | | | | | | | | | | | |
| 11 | 5 | 3 | | | | | | | | | | | | | | |
| 12 | 4 | 5 | | | | | | | | | | | | | | |
| 13 | 7 | 3 | | | | | | | | | | | | | | |
| 14 | 5 | 4 | | | | | | | | | | | | | | |
| 15 | 4 | 3 | | | | | | | | | | | | | | |
| 16 | 5 | 5 | | | | | | | | | | | | | | |
| 17 | 5 | 4 | | | | | | | | | | | | | | |
| 18 | 5 | 3 | | | | | | | | | | | | | | |
| 19 | 5 | 3 | | | | | | | | | | | | | | |
| 20 | 10 | 5 | | | | | | | | | | | | | | |
| 21 | 5 | 2 | | | | | | | | | | | | | | |
| 22 | 7 | 5 | | | | | | | | | | | | | | |
| 23 | 5 | 4 | | | | | | | | | | | | | | |
| 24 | 5 | 4 | | | | | | | | | | | | | | |
| 25 | 6 | 3 | | | | | | | | | | | | | | |
| 26 | 7 | 4 | | | | | | | | | | | | | | |
| 27 | 7 | 4 | | | | | | | | | | | | | | |
| 28 | 4 | 2 | | | | | | | | | | | | | | |
| 29 | 3 | 5 | | | | | | | | | | | | | | |
| 30 | 4 | 4 | | | | | | | | | | | | | | |
| 31 | 6 | 3 | | | | | | | | | | | | | | |
| 32 | 6 | 4 | | | | | | | | | | | | | | |

N. — **Record of the number of rails of various lengths from each cast.** (*Continued.*)

| Cast number. | NUMBER OF RAILS : 18.000 m | | 17.88 m. | | 18.000 m | | 17.88 m | | 18.000 m | | 17.88 m | | 18.000 m. | | 17.88 m. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. |
| 33 | 3 | 6 | | | | | | | | | | | | | | |
| 34 | 7 | 5 | | | | | | | | | | | | | | |
| 35 | 5 | 5 | | | | | | | | | | | | | | |
| 36 | 4 | 3 | | | | | | | | | | | | | | |
| 37 | 5 | 4 | | | | | | | | | | | | | | |
| 38 | 4 | 3 | | | | | | | | | | | | | | |
| 39 | 4 | 3 | | | | | | | | | | | | | | |
| 40 | 5 | 4 | | | | | | | | | | | | | | |
| 41 | 5 | 3 | | | | | | | | | | | | | | |
| 42 | 4 | 2 | | | | | | | | | | | | | | |
| 43 | 4 | 5 | | | | | | | | | | | | | | |
| 44 | 3 | 4 | | | | | | | | | | | | | | |
| 45 | 5 | 2 | | | | | | | | | | | | | | |
| 46 | 5 | 5 | | | | | | | | | | | | | | |
| 47 | 5 | 4 | | | | | | | | | | | | | | |
| 48 | 3 | 1 | | | | | | | | | | | | | | |
| 49 | 9 | 3 | | | | | | | | | | | | | | |
| 50 | 5 | 4 | | | | | | | | | | | | | | |
| 51 | 6 | 5 | | | | | | | | | | | | | | |
| 52 | 4 | 6 | | | | | | | | | | | | | | |
| 53 | 7 | 3 | | | | | | | | | | | | | | |
| 54 | 5 | 3 | 1 | | | | | | | | | | | | | |
| 55 | 5 | 4 | | | | | | | | | | | | | | |
| 56 | 7 | 4 | | | | | | | | | | | | | | |
| 57 | 5 | 4 | | | | | | | | | | | | | | |
| 58 | 10 | 3 | | | | | | | | | | | | | | |
| 59 | 8 | 5 | | | | | | | | | | | | | | |
| 60 | 9 | 4 | | | | | | | | | | | | | | |
| 61 | 9 | 5 | | | | | | | | | | | | | | |
| 62 | 5 | 5 | | | | | | | | | | | | | | |
| 63 | 4 | 3 | | | | | | | | | | | | | | |
| 64 | 7 | 5 | | | | | | | | | | | | | | |

N. — **Record of the number of rails of various lengths from each cast.** (*Continued.*)

| Cast number. | NUMBER OF RAILS : | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 18.000 m | | 17.88 m. | | 18.000 m | | 17.88 m. | | 18.000 m. | | 17.88 m. | | 18.000 m. | | 17.88 m. | |
| | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. |
| 65 | 4 | 4 | 1 | | | | | | | | | | | | | |
| 66 | 3 | 6 | | | | | | | | | | | | | | |
| 67 | 6 | 5 | | | | | | | | | | | | | | |
| 68 | 6 | 4 | | | | | | | | | | | | | | |
| 69 | 6 | 4 | 1 | | | | | | | | | | | | | |
| 70 | 6 | 6 | 1 | | | | | | | | | | | | | |
| 71 | 7 | 5 | | | | | | | | | | | | | | |
| 72 | 8 | 4 | | | | | | | | | | | | | | |
| 73 | 6 | 5 | | | | | | | | | | | | | | |
| 74 | 5 | 3 | | | | | | | | | | | | | | |
| 75 | 8 | 3 | | | | | | | | | | | | | | |
| 76 | 5 | 4 | | | | | | | | | | | | | | |
| 77 | 5 | 3 | | | | | | | | | | | | | | |
| 78 | 5 | 9 | | | | | | | | | | | | | | |
| 79 | 8 | 5 | | | | | | | | | | | | | | |
| 80 | 3 | 3 | | | | | | | | | | | | | | |
| 81 | 4 | 6 | | | | | | | | | | | | | | |
| 82 | 4 | 4 | | | | | | | | | | | | | | |
| 83 | 6 | 6 | | | | | | | | | | | | | | |
| 84 | 8 | 6 | | | | | | | | | | | | | | |
| 85 | 7 | 4 | | | | | | | | | | | | | | |
| 86 | 5 | 4 | | | | | | | | | | | | | | |
| 87 | 4 | 5 | | | | | | | | | | | | | | |
| 88 | 5 | 4 | | | | | | | | | | | | | | |
| 89 | 5 | 5 | | | | | | | | | | | | | | |
| 90 | 8 | 6 | 1 | | | | | | | | | | | | | |
| 91 | 9 | 5 | | | | | | | | | | | | | | |
| 92 | 8 | 7 | | | | | | | | | | | | | | |
| 93 | 4 | 5 | | | | | | | | | | | | | | |
| 94 | 6 | 4 | | | | | | | | | | | | | | |
| 95 | 7 | 5 | | | | | | | | | | | | | | |
| 96 | 5 | 5 | | | | | | | | | | | | | | |

N. — **Record of the number of rails of various lengths from each cast.** (*Continued.*)

| Cast number. | NUMBER OF RAILS. | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 18.000 m. | | 17.88 m. | | 18.000 m. | | 17.88 m. | | 18.000 m. | | 17.88 m. | | 18.000 m. | | 17.88 m. | |
| | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. | Bottom of ingot. | Top of ingot. |
| 97 | 8 | 4 | | | | | | | | | | | | | | |
| 98 | 7 | 3 | | | | | | | | | | | | | | |
| 99 | 5 | 2 | | | | | | | | | | | | | | |
| 100 | 4 | 2 | | | | | | | | | | | | | | |
| 101 | 9 | 6 | | | | | | | | | | | | | | |
| 102 | 5 | 2 | | | | | | | | | | | | | | |
| 103 | 4 | 7 | | | | | | | | | | | | | | |
| 104 | 9 | 4 | | | | | | | | | | | | | | |
| 105 | 8 | 4 | | | | | | | | | | | | | | |
| 106 | 5 | 3 | | | | | | | | | | | | | | |
| 107 | 7 | 4 | | | | | | | | | | | | | | |
| 108 | 5 | 4 | | | | | | | | | | | | | | |
| 109 | 5 | 5 | | | | | | | | | | | | | | |
| 110 | 6 | 5 | | | | | | | | | | | | | | |
| 111 | 5 | 4 | | | | | | | | | | | | | | |
| 112 | 7 | 5 | | | | | | | | | | | | | | |
| 113 | 8 | 3 | 1 | | | | | | | | | | | | | |
| 114 | 7 | 4 | | | | | | | | | | | | | | |
| 115 | 8 | 3 | 1 | | | | | | | | | | | | | |
| 116 | 6 | 5 | 1 | | | | | | | | | | | | | |
| 117 | 7 | 4 | | | | | | | | | | | | | | |

[ 625 .143.2 (.44) ]

# Note on the new French railway specifications for steel rails,

By L. CAMBOURNAC,
CHIEF ENGINEER FOR BRIDGES, PERMANENT WAY AND BUILDINGS,
FRENCH NORTHERN RAILWAY.

Figs. 1 to 3, pp. 1003 and 1004.

(*Revue Générale des Chemins de fer.*)

Before the war, the principal French railways had put in hand the preparation of a Standard Specification to which steel rails would be obtained.

This unification had become necessary in consequence of the types of rails having been standardised (1) and its preparation, interrupted by the war, was continued as soon as circumstances permitted.

The work ended with the publication of the new Specification which was officially adopted as from July 1923. As a matter of fact most of the principal Companies had forestalled its publication by including in their post-war contracts the principal requirements of the new Specification, so that whilst admitting that it is too early to form any final judgment on it, the results obtained have been such as to allow it to be said that the new Specification is an improvement upon those in use before the war by the different French Companies, and to bring also out those points which require improvement in any future issue. For these reasons we think that the new Specification, the complete text of which is given at the end of this note, should be brought to the attention of Railway engineers. It should be added that before the Specification was finally printed, the draft was submitted to the French Steel Makers manufacturing rails and that their suggestions were to a large extent given effect to.

It can therefore be said that under present conditions in the French steel trade, the Specification lays down the conditions the Railway Companies consider the rails should meet in order to give the best results in service.

We give below a concise commentary on the principal requirements of the Standard Specification.

## ANALYSIS OF THE SPECIFICATION.

### ARTICLE 1.
### General Requirements.

Paragraph 2 allows the rails to be made from three classes of steel classified in accordance with the tensile tests. The three kinds correspond to minimum resistances of 65, 70 and 80 kgr. per square millimetre (41.3, 44.4, and 50.8 English tons per square inch).

The Midi Company before the war ordered rails of 80 kgr. tensile which other Companies used for points and crossings, etc., although using for ordinary purposes rails of from 65 to 70 kgr. tensile.

(1) See in the November, 1920 number of the *Revue Générale des Chemins de fer*, article by M. Frœbé, principal engineer for buildings, etc., of the French State Railways.

From the information available there appeared *a priori* no good reason for excluding one of the grades then in general use, and it seemed preferable to continue to use generally the three qualities of 65, 70 and 80 kgr. tensile. A more thorough investigation may at some future date allow a better choice to be made from them.

Paragraph 3*b*, allowed the railways to require or to exclude certain methods of manufacture of the steel. There is far from unanimity of opinion as to the relative value of the different methods of manufacture so far as they affect brittleness and resistance to wear. It seemed advisable therefore to make such arrangements that would allow the use of rails made by different processes for comparative purposes.

We would add that in spite of the restrictions introduced at the request of the steel makers with regard to the 80 kgr. tensile quality (last paragraph) several makers of steel by the Thomas process have supplied rails of this quality. We shall deal with this later.

ARTICLE 2.

**Method of manufacture**

Paragraph 1 : *Method of manufacture of the steel.* — The development of steel for rail making is essentially a matter for the metallurgist, and it is advisable to leave to the steel maker the greatest liberty the railway engineer can compatible with safety.

The railway engineer alone can know how rails behave in service : it is his business to investigate breakages and rail wear, to consider them in conjunction with the method of manufacture, and to call the attention of the metallurgist to the effect of any particular method of manufacture on the quality of the rails.

Improvement in the quality of rails can only be made if there is enlightened and frank collaboration between the metallurgist and the railway engineer. It presupposes firstly as full data as possible on the circumstances in which the rails were made, as well as on the conditions under which the rails were used. For these reasons article 2, paragraph 1, of the new Specification, lays down that the metallurgist shall advise the railway Company of the more important details of the method of manufacture of the steel for the rails, and especially give particulars of any additions made during and after refining to bring the metal to its final composition.

In the present state of knowledge it has not seemed possible to definitely refuse to allow any particular process to be used. Research is being made into two much discussed practices, to wit, recarburation, total or partial, by means of anthracite, and the addition of aluminium in the ingot chargers.

Paragraph 2 : *Regularity of chemical composition.* — Paragraph 2 was drawn up in order that full data may be collected, and also to ensure regular and consistent manufacture, the regularity of composition being in itself a sign of good quality metal. Unlike most Specifications formerly in use, the new text lays down no limits of the content of certain metalloids (phosphorus, sulphur, manganese), excess of which, as is known, makes the metal brittle.

It should be stated however that the limit in question is rather a delicate matter, as a high content does not constitute an invariable criterion. A phosphorus content which should not be accepted in the case of one mixture of carbon silicon and manganese, could be accepted for another. There is therefore a risk of being either too difficult and thereby refusing to accept rails that would give good service, or of being not difficult enough and thereby accepting rails of doubtful quality.

Furthermore, the drop test, which is dealt with later, appeared to reveal any brittleness due to the chemical compo-

sition of the metal more surely than the chemical analyses, which in spite of the care with which they are made, are often marked by inexactitudes. The chemical analyses which have been taken to obtain information as to the chemical composition of the steel and the drop tetsts are being compared as manufacture proceeds, and so far any necessity for limiting the content of certain metalloids has not been seen.

Paragraph 3 : *Casting and rolling.* — It will be noted that in the present Specification nothing is said as to the method of pouring the ingot moulds.

It appears to be admitted that the temperature of the metal when being poured, and the method of pouring adopted, have a direct influence on piping and segregation, which, when present, are serious defects in steel for rails.

In the present state of knowledge it has not been possible to lay down definitely the conditions and method of pouring. This question is one of the most important that is occupying the attention of the metallurgists and the railway engineers.

The final rolling temperature is a factor which must not be neglected. It is advisable that it be as low as possible. It should not be impossible to lay down the maximum temperature allowed, and by simple methods see that it is not exceeded. At a later date the Specification could include this point.

Paragraph 5 : *Discard.* — The paragraph prescribes a top discard of not less than 12 % of the weight of the ingot.

Although in the case of the method of manufacture, the chemical composition, and the method of pouring, he has not been allowed to do so, in this respect the railway engineer enters the province of the metallurgist. He is not content to say that the top part cut of shall be such that the bar, after the discard has been removed, shall fulfil the requirements of the Specification, but lays down the minimum discard and appears thereby to lay down a limit to the improvement the metallurgist can make in his manufacturing methods. It should be said that the minimum of 12 % laid down is notably less than the discard actually made in French steel works, 18 % being the usual allowance « so that the bloom after rolling shall fulfil the requirements and be passed ». A margin for improvement, which is far from negligible, is consequently left to the metallurgist.

A minimum discard is specified for the following reason. Usually in the rolled bar next to the unfinished end the metal is relatively good, up to even 8 % of the length of the bar. This piece is followed by a part piped and shewing segregation which extends to 15 % of the length of the bar, and even more. If the minimum discard were not laid down there would be danger of getting good drop tests on test pieces taken from the top where the metal is good, and therefrom accepting as sound the defective part of the bar. In laying down a minimum of 12 % this danger is avoided. The drop tests are thereby made on test pieces that in almost every case contains at least as many defects of structure or composition as the rails being inspected.

Paragraph 7 : *Cold straightening of rails.* — Some cases of broken rails have been ascribed to change of structure of the metal, resulting from straightening when cold, either in a press or by rolling, which would not be surprising in view of the localised stresses which the rail has to stand when being so straightened. The present Specification does not call the attention of the Companies to such changes except when they result in surface and visible defects (article 4, paragraph 1). So far it has not seemed possible to lay down anything more detailed, but in the future it will be necessary to carry the study of this matter

further, either with a view to revealing the internal or invisible changes in the bar, or to define the method of straightening the bar or even to disallow certain methods or machines.

The other paragraphs of article 2, some of which are very different from the clauses of previous Specifications, do not call for any particular remark. For information, however, we may point out that the density of 7.840 of the steel given in paragraph II was obtained from the mean of many tests made at the same time by several of the Railways.

### Article 3.

### Material offered for inspection.

One of the principal innovations of the specification is that a drop test is required from each ingot and not from any given number or tonnage of rails from several casts or even from each cast. In view of the large number of discards to be kept for the tests, it is essential if errors are to be avoided that the marking and grouping of the rails and discards be done most methodically.

Article 3 has been prepared with this object, and furthermore makes the management of the works responsible for seeing that material for test is properly prepared.

The works as well as the railways have every reason for avoiding every inaccuracy or doubt in these operations. With this object in view some of them have installed mechanical devices for stamping the rails whilst hot as they leave the rolling mill. It is to be hoped that this arrangement will be extended. It is quite possible that later on the specification may make it obligatory.

The last phrase in paragraph 1, put in at the request of the steel makers, has rarely been taken advantage of, most of the works having sufficient room to store, whilst waiting for the Railway Company's inspector, the discards from several days' output.

### Article 4.

### Exterior inspection.

Paragraph 1: *Examination of the surface of the rails.* — The Specification states briefly the most characteristic surface defects the Railway Company's inspector looks for during inspection. Some of these defects are not easily observed, as, for example, cracks due to piping or segregation in the end section of the rails; and the very fine longitudinal cracks in the flange caused sometimes by straightening the rails cold by rolling.

The railway inspectors should have at their disposal better equipment for carrying out their investigations than they have at present, and, with this object in view, research work is being carried out.

The other paragraphs of this clause call for no particular comment.

The tolerances on dimensions meet the requirements of the railways and are easily met by the makers.

### Article 5.

### Particulars of tests to be made before acceptance.

The only tests imposed by the Specification with a view to eliminating defective material are the drop and tensile tests.

The drop test is made with a tup of 300 kgr. (660 lb.) and a rigid anvil of 10 000 kgr. (22 000 lb.). The tensile test is carried out in accordance with the method given in the *Recueil des Méthodes d'essais mécaniques usuelles unifiées.*

We have already stated above that the chemical analysis is asked for only for information, and, unlike certain foreign specifications, the material cannot be rejected because of it.

The Specification also includes for information only a Brinell hardness test.

Article 7, paragraph 2 shews how the inspector when passing material is guid-

ed by these tests which are such as to satisfy anyone as to uniformity of manufacture.

Although segregation and the defects that go with it, blow holes, non-metallic inclusions, etc., are considered by railway engineers as the causes of ultimate failure and defects in rails in service, the present Specification includes no test to reveal segregation. In the present state of our knowledge, macrographs give interesting information, but only qualitatively. They reveal the presence of segregation, sometimes even the cracks in the part segregated, but do not give any idea as to the extent that such segregation makes the metal brittle. The same can also be said we think of the quantitative chemical analyses, which are difficult to make, required by some foreign specifications. Properly speaking, it is not the segregation that has to be proscribed and therefore ascertained and even measured, but the brittleness due to excessive segregation. It is in order to be warned against this brittleness that the drop test on a piece of rail with a milled notch, the second and principal innovation of the present Specification, was introduced. We will now consider this.

### Article 6.

### Test pieces.

Whereas in the case of the tensile test only one test piece per cast is specified, in the case of the drop test a test piece per ingot is required (article 6, paragraph 1).

Further, this drop test is now made on a notched piece of rail, whereas formerly it was made on a bar of full section (article 6, paragraph 2). In other words, if the authors of the Specification did not feel obliged to take greater care to prevent softer rails than those ordered being offered, they have thought it desirable to increase and perfect the drop tests as these should reveal any brittleness of the metal, which affects directly the safety of railway working.

When in the road the rails carry the traffic without assistance, the failure of any one of them possibly causing an accident. As in the case of certain parts of metal frames, or parts of machines, carrying the load unassisted, it was thought the rails should be tested one by one.

Such tests would be difficult to carry out, and further seemed hardly necessary if the tests could be made with short lengths of bars, provided there was some certainty that these were likely to have the same defective structure or composition as the rails to be inspected. The result desired is obtained firstly by stating the minimum top discard allowed (article 2, paragraph 5) mentioned above, and secondly by making a test from the top of each ingot.

For these reasons a test per cast appeared to be insufficient. Different ingots from the same cast cannot be supposed to be identical. The temperature of pouring and the way the ingot is cooled differ and, as is well known, directly affect the segregation. There is still greater difference if additions, and especially of aluminium, are made to the moulds.

A drop test has therefore to be taken from each ingot. Further, the short length tested by the drop test is notched at its centre across the head, as shewn in paragraph 2. The section which carries the maximum load under the drop is therefore the weakest of the test piece. In addition, in this section the fibres which take the greatest breaking strain, instead of being on the outside of the rail where the metal is always most homogeneous and toughest, are in the middle, of the section, where all defects due to bad metal, insufficient discard, segregation, blow holes, presence of non-metallic inclusion, etc., are to be found.

The drop test on a notched rail should therefore reveal, not only the brittleness

of metal due to its chemical composition as would a length of full section, but also bring to light the internal heterogeneity of the metal — one of the main causes of defective and broken rails in service.

The drop test per ingot, and the drop test on a notched length of rail, are the really new features in the standard Specification, and it is only reasonable to mention their author (1) — Mr. Ch. Fremont — whose valuable studies of the causes and symptoms of defects in rails have been of great assistance to the authors of the Specification.

### Article 7.

**Results required to be given by tests.**

The height of drop specified in paragraph 1 for rails of 65 kgr. (41.3 English tons per square inch) tensile and the other conditions laid down for the drop test (weight of tup, distance apart of supports, length of test piece, depth of milled notch) have been determined from the results of many tests made by the Railways at various steel works, and in particular by the Eastern Railway at the Usines de la Providence at Rehon (Meurthe-et-Moselle).

The drop test carried out in this way is distinctly more severe than those required by former Specifications.

We have had many opportunities of proving that this test definitely reveals any want of homogeneity in the metal. If a number of test bars are cut out of a section of rail adjacent one to the other, and are tested for resilience, we found that we could not get a satisfactory drop test from a notched length of rail if any of these bars did not give the normal resilience.

Obviously the actual conditions under which the drop tests are made are not such that they are inevitably final. Any or many of them may be easily altered if, after a lengthy use of the Specification, it is found necessary to do so.

It will be noted that the drop test for the 70 and 80 kgr. (44.4 and 50.8 English tons per square inch) tensile rails is rather easier, the height of drop of the tup being less than in the case of the 65 kgr. (41.3 English tons per square inch) rail. At first view this seems logical as resistance to shock diminishes as the tensile increases in the case of carbon steels. On the other hand, however, the rails, regardless of quality, have to carry the same loads and should therefore undergo the same drop test.

Tests have been made on rails made by the Bessemer, and Martin, and also by the Thomas processes, and have shewn that it would be quite possible even in the case of the hardest quality (80 kgr. tensile) to specify the same drop as in the case of the softest (65 kgr.).

It is therefore probable that later on the Specification will require the same drop for all qualities of steel.

In order to reduce the number of drop tests, and at the request of the steel makers, paragraph 1 allowed the test per ingot to be waived if each ingot of five successive casts had given satisfactory drop tests. So far the railways have taken advantage of this clause in rare cases only, as it cuts across the principle of a test from each ingot, the reasons for which have been given above, an alteration which only a long experience of the Specification could shew to be justified.

The number of tests could be reduced by not testing the last ingots from a cast, and rejecting the whole cast if the first ingots, up to say, two-thirds of the total, did not come up to the drop test. This stipulation does not appear in the present Specification but a clause of this kind might be added later on.

(1) 39th Paper : New methods of testing rails, 1911. — 58th Paper : Causes of undue wear of rails, 1921. — 61st Paper : Causes of accidental breakages of rails, 1922. — 69th : Wear and defects in rails, 1924.

The tensile test, paragraph 2, does not require any particular notice. It should be noted, however, that the test piece is always taken from the bottom discard instead of as selected by the inspector under some specifications.

The possibility of such selection, sometimes from the top and sometimes from the bottom, interfered with the regularity of manufacture in the opinion of the metallurgists, and it did not seem necessary to retain it.

The tension test, athough far from perfect, involves much preparatory work, and it is very desirable, as technical knowledge advances, that some simpler and quicker test to differentiate the quality of steel be found to take its place.

ARTICLE 8

**Stamping of the rails.**

The stamping of the rail does not include any mark to indicate the Railway that gave the order. The same rolls can therefore be used for rails for several railways without alteration. This is one of the advantages that has resulted from the standardisation of sections and from the standard Specification for rails.

ARTICLE 9.

**Guarantees.**

**Makers' responsibility.**

The present Specification introduces nothing new with regard to the principle and extent of the makers' responsibility. Common right governs the two parties.

Defective or broken rails should be replaced, not in kind, but by their value during the guarantee period which has been fixed at 10 years.

## SUMMARY AND CONCLUSIONS.

The short analysis we have just made shews the care taken by the authors of the Specification to eliminate from the text all phrases and requirements not absolutely necessary, and thereby to retain as eliminating tests two simple and easily interpreted tests, the drop and tensile tests.

They have preferred to increase the number of drop tests so that there should be one per ingot, and to perfect the method of carrying it out by substituting for a complete section a notched section.

Whether any of the tests given up will have to be re-introduced, or any of the tests retained modified, can only be known after the Specification has been in use some considerable time.

The points wherein improvement might be looked for have been stated.

It is for the railway engineers to follow up the question of improving the Specification, as they alone know how the rails behave in that great experimental laboratory — the French railway system.

By orderly examination of breakages and defects found during the first years the Specification is in use, analysing them, and considering them in conjunction with the conditions of manufacture and inspection, progress can be made. The attention of the engineers whose duty it is to see that the track can safely carry the always increasingly heavy and fast traffic cannot be too insistently called to the importance of this investigation.

## SPECIFICATION FOR STEEL RAILS

### Art. 1. — General arrangements.

Paragraph 1 : *Object of the Specification.* — The present Specification defines the conditions under which all types of rail will be inspected.

Paragraph 2 : *Classes of steel.* — The classification of the steel by grade is based on the tensile test as given in article 7, paragraph 2. According to this classification the grade is described by the minimum tensile resistance which is taken as the principal characteristic of the steel.

There are three grades, those of 65, 70 and 80 kgr. (41.3, 44.4 and 50.8 English tons per square inch).

Paragraph 3 : *Wording of orders.* — *a*) After stating the types, lengths, number or tonnage of each type with the lengths, the order shall state :

1) The specification to be followed, giving its number and date of issue;

2) The minimum resistance laid down for the steel (65 kgr., 70 kgr., or 80 kgr.) (article 1, paragraph 2);

3) The longitudinal tolerances admitted in the spacing of holes other than for fish plate bolts (article 4, paragraph 2*d*);

4) The depth P of the milled notch for rails other than standard and rails actually in use on the principal French Companies (article 6, paragraph 2).

*b*) The order can require or exclude certain processes of steel manufacture — Thomas, Martin, Bessemer, or other — it being understood that for steel of 80 kgr. grade (50.8. English tons per square inch) the Thomas process can not be stipulated.

### Art. 2. — Method of manufacture.

Paragraph 1 : *The method of manufacture of the steel* (Thomas, Bessemer, Martin, or other) shall be stated on the order.

The maker shall advise the Railway Company as to the principal features of the method he will follow in applying the said process. He will in particular state the additions made during and after refining to bring the metal to its final composition. The supplier shall not alter his method of manufacture without notifying the Railway Company's inspector.

Paragraph 2 : *Regularity of chemical composition.* — The metal used for making the rails shall be of the same chemical composition.

The works shall give the inspector all information necessary to satisfy him on this point. For this reason each cast shall be analysed in the maker's laboratory, the analyses being entered in a register which the Inspector shall see when he wishes to do so. The quantities of carbon, manganese and phosphorus shall be given in each analysis of each cast.

When the Railway Company requires it, the maker shall carry out in his laboratory by the most precise methods known, a complete analysis of the casts indicated, giving the carbon, manganese, silicon, sulphur and phosphorus content. Not more than one analysis per 100 tons of rails shall be made.

Paragraph 3 : *Casting and rolling.* — Under no circumstances shall the ingot be of a section of less than 20 times that of the rolled rail; it must not be laid down before complete solidification. The rails shall be rolled smooth and free from defects.

The final rolling temperature to be as low as possible.

Paragraph 4 : *Profile.* The profile of the rails shall be as shewn on the drawings or stamped gauges sent to the works by the Railway Company. (See « Tolerances », article 4, paragraph 2*c*.)

Paragraph 5 : *Discards.* — The discard from the top end of the ingot shall be such that the bloom or rail bar after cropping shall meet the requirements; the discard shall be such that a length of 700 mm. (2 ft. 3 1/2 in.) can be taken from it for the drop test bar (article 7, paragraph 1).

The weight of the discards must not be less than 12 % of that of the ingot.

At the other end of the bloom the discard shall be long enough to allow of a piece of 300 mm. (11 13/16 inches) being cut out of it for the tensile test (article 7, paragraph 2).

Paragraph 6 : *Hot straightening.* — The rails shall be allowed to cool off in such manner that the deformations due to cooling tend to straighten them. When cooling they are to be sheltered from rain, snow and any contact with water until cooled down to the temperature of the surrounding atmosphere.

Paragraph 7 : *Cold straightening.* — The rails shall be straightened by gradual pressure without shock in order to avoid any damage to the metal.

Paragraph 8 : *Cutting to length.* — The rail shall be cut to length cold by milling or any other method giving the same result. The burrs shall be removed by filing, they shall not be removed by chipping. The ends shall be true and square with the axes of the rail. (See « Tolerances », article 4, paragraph 2*c*.)

Paragraph 9 : *Drilling.* — The rails shall be drilled through the web, with round or oval holes as shewn on the drawing. (See « Tolerances », article 4, paragraph 2*d*.)

The holes shall be drilled by tools to give smooth holes, without heating the metal so as to damage it. The burrs shall be removed by filing or milling.

Paragraph 10 : *Repair.* — No attempt to cover up or hide defects must be made when the rails are either hot or cold.

Paragraph 11 : *Weight of the rails.* — The normal weight allowed per metre for each profile is calculated on a specific gravity of 7.840.

For each lot manufactured the weight of rails delivered is arrived at by multiplying the length of the rails by the mean weight per metre ascertained by weighing twenty long bars selected equally by the works and the inspector. The weight thus ascertained shall not vary by more than 2 % from the normal weight — if below thus, the rails will not be passed; if above, the excess weight will not be paid for.

Subject to this reserve, the rails of each delivery shall be paid for on the weight calculated as above. If the whole of the rails delivered exceed the normal weight by more than 1 %, the excess shall not be paid for.

Paragraph 12 : *Inspection.* — The inspector shall be at liberty to follow the manufacture at all times, to see all tests and analyses made by the works in connection with the casts in which he is interested, or to ascertain the results, and to take all steps necessary to ensure that all the requirements of the specification are met during manufacture.

The inspector shall address any remarks he has to make to the manager of the works and not to the foreman or men.

ART. 3. — Presentation of material.

Paragraph 1 : *Stacking of rails.* — The rails shall be offered for inspection as far as possible by casts. The top and bottom discards of the ingots shall be grouped by casts, the numbers of the casts and of the ingots being readily seen.

The groups shall be left until the inspector has selected the bars to be tested.

If the selection is not made within 24 hours after the cast has been rolled, the works can, if they find it necessary, remove them after having first selected the necessary test bars.

Paragraph 2 : *Advice note.* — The advice note shall be handed by the works to the inspector. The note properly signed and drawn up by the manager of the works, shall restate the conditions of the order and serve as a certificate that the methods of manufacture and of marking required by paragraphs 1, 3, 5, 7 and 10 of article 2 and by article 8, have been fulfilled.

Further, it shall certify that the rails have not been previously submitted for inspection. The manufacturer shall provide the necessary labour to enable the inspector to examine the four sides and both ends of the rails for defects.

ART. 4. — **Exterior inspection of the rails.**

Paragraph 1 : *Surface examination.* — *a*) The four sides and the ends shall be free from any defects, twists, cracks, flaws, blisters, etc.;

*b*) Surface defects shall be cut out by chisel. If, after this has been done, the tolerances allowed are exceeded, the inspector can accept the rails if he consider the defects will not affect the service given by the rail.

Paragraph 2 : *Tolerances on the dimensions.*
*a*) LENGTH. — The lengths specified are at a temperature of 15° C. (59° F.) and are measured along the web.

The tolerance on the length shall be plus or minus :

2 millimetres (0.079 inch) on lengths of 18 m. (59 ft. 5/8 in.) or less;

3 millimetres (0.118 inch) on lengths of from 18 m. to 24 m. (59 ft. 5/8 in. to 78 ft. 9 in.) inclusive;

*b*) SECTIONAL DIMENSIONS. — An allowance of half a millimetre (0.0197 inch) plus or minus is allowed on the profile dimensions on condition that the actual weight of the rail shall not be 2 % above or below the normal weight as defined in article 2, paragraph 11.

For flat bottomed rails the tolerance on the flange shall be 1 millimetre (0.039 inch) plus or minus;

*c*) SQUARING OF ENDS. — A tolerance of half a millimetre (0.0197 inch) shall be allowed;

*d*) DRILLING. — A difference of half a millimetre plus or minus shall be allowed in the diameter of the holes. A difference of 1 millimetre plus or minus shall be allowed in spacing the fish plate bolt holes. The distance of the fish plate bolt holes from the rail end shall be checked by means of a gauge with a stop to engage the rail end and two studs which should enter the holes.

The studs shall be 1 millimetre less in diameter than the corresponding diameter of the holes. The centres of the studs from the stop shall be exactly the same as the centres of the holes from the rail end.

All the studs must enter the holes in the rail at the same time with the stop in contact with the rail end.

The orders will state the tolerances allowed longitudinally for all holes other than those for the fish plate bolts.

Paragraph 3 : *Gauges.* — The gauges for checking the profile, drilling, etc., shall be provided by the maker at his cost. The precision gauges belonging to the railway will not relieve the maker from preparing his own gauges as the Railway Company's gauges are to be used to test these other gauges and not the manufactured material.

ART. 5. — **Tests to be made before rails are accepted.**

Paragraph 1 : *List of tests.* — The rails offered for inspection shall be submitted to the following tests :

*a*) DROP TEST ON A NOTCHED PIECE OF RAIL;
*b*) TENSILE TEST;
*c*) HARDNESS TEST (for information only).

Paragraph 2 : *Method of making tests.* —
*a*) DROP TEST ON A NOTCHED PIECE OF RAIL.

The drop test on a notched piece of rail shall be made with a guided tup weighing 300 kgr. (660 lb.).

The guides shall be rigid, straight and vertical, and so arranged that the friction during the drop shall be reduced to the minimum.

The mass and form of the tup shall be symmetrical with reference to the plane of the guides. The centre of gravity shall be as low as possible in this plane, and in the vertical plane should be equidistant between the two guides.

The height of the guide ways of the tup shall be appreciably greater than the distance between the guides.

The release gear shall not cause any side movement of the tup when operated.

The base shall be cylindrical in the horizontal plane in line with the guides and conform to the design shewn in figure 1. The weight of the metal anvil shall be not less than 10 000 kgr. (22 000 lb.).


Fig. 1.

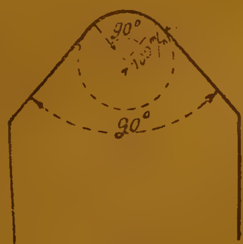



Fig. 2.

The supports for the rails shall be spaced at 0.500 m. (1 ft. 7 11/16 in.) centres; they shall be fixed to the anvil so that they cannot be displaced and be of the form shewn in figure 2.

The base of the tup and the top of the rail supports shall be repaired or renewed when damaged;

*b*) TENSILE TEST;

*c*) HARDNESS TEST (for information only).

These tests *b*) and *c*) shall be carried out as required by the *Recueil des Méthodes d'essais mécaniques usuelles unifiées.*

ART. 6. — **Preparation of test pieces.**

Paragraph 1 : *Method of selecting test pieces.* — The inspector shall select each day from the top and bottom discards of each cast from the side opposite to the rough end :

1) Top discard : a bar of 0.700 m. (2 ft. 3 1/2 in.) per ingot for the drop test;

2) Bottom discard : a bar of 0.300 m. (11 13/16 inches) per cast for the tensile test.

The tensile test pieces shall be cut out cold in the upper 2/5th of the rail head measured between the top face of the rail and the horizontal line through the intersection of the web and the underside of the head.

Paragraph 2 : *Dimensions of test pieces.* — *a*) The 0.700 m. length of rail for test will have a notch milled across the top at the centre of its length with a cylindrical mill 0.100 m. (3 15/16 inches) in diameter, as shewn in figure 3. The depth P of the milled notch should be equal to 2/5th of the depth of the head of the rail measured as described above in article 6, paragraph 1.

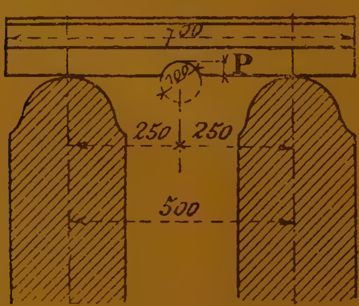



Fig. 3.

The above formula is to be applied to standard rail profiles and to the present profiles in use on the principal French Companies.

For all other rails the depth P shall be stated on the order.

*b*) The tensile test piece shall be of the form and size prescribed in the *Recueil des Méthodes d'essais mécaniques usuelles unifiées.*

Paragraph 3 : *Stamping test pieces.* — All identification marks shall be scribed, located and stamped under the supervision of the inspector. Marks can only be removed and restamped during the preparation of the test pieces in the presence of the inspector. When ready, the tensile test pieces must be stamped at both ends with the Railway Company's stamp.

Paragraph 4 : *Treatment of test pieces.* — The test pieces shall be cut cold and not be submitted to any hammering, cold working, tempering, or annealing.

ART. 7. — **Results to be given by tests.**

Paragraph 1 : *Drop test on notched rail.* — The piece of rail with milled notch prepared in accordance with article 6, paragraph 2*a*, and at a temperature above 0° C. (32° F.), shall be placed on the anvil so that the head rest upon the supports, it shall stand without fracture a blow from the tup falling a height in metres equal to the weight of the rail per metre in kilogrammes multiplied by the coefficient given below :

0.10 for rails of 65 kgr. quality.
0.095 for rails of 70 kgr. quality;
0.090 for rails of 80 kgr. quality.

As a general rule, a test shall be made from each ingot. When all the ingots from five successive casts of steel of the same melt shall have given satisfactory drop tests the Railway can, if it so desire, reduce the number of tests, provided that not less than two tests per cast are made, and that every ingot shall be tested if from any one ingot of a cast the test has not been satisfactory.

If the test from the top discard is unsatisfactory, the bar H from this ingot shall be put aside and a new test shall be made from the bottom end.

If this test be satisfactory, the rest of the ingot shall be accepted provided all other re-

quirements of the specification are met : if otherwise, the whole ingot shall be rejected.

Paragraph 2 : *Tensile test.* — The tensile test pieces shall be prepared in accordance with article 6, paragraph 2*b*, and give the following results :

| GRADE. | Minimum Resistance in kilogrammes per square millim. (in English tons per square inch) of the original section. | Minimum Percentage Elongation on a length of 100 millimetres 3 15/16 inches). | *Observations.* |
|---|---|---|---|
| 65 kgr. | 65 (41.3) | 10 % | The Resistance R and the Elongation A shall be in accordance with the formula $R + 2A \geqslant 92$. |
| 70 kgr. | 70 (44.4) | 9 % | The Resistance R and the Elongation A shall be in accordance with the formula $R + 2A \geqslant 94$. |
| 80 kgr. | 80 (50.8) | 7 % | The Resistance R and the Elongation A shall be in accordance with the formula $R + 2A \geqslant 98$. |

For each of the three grades the rails will be grouped by lots in order of rolling from ingots from three casts which have fulfilled the requirements of the drop test.

A tensile test shall be made from each of the lots in question. The test piece shall be taken at the option of the inspector in accordance with information revealed by the hardness test, or the analyses from the discard from the base, which he shall indicate.

If this test is satisfactory the lot of rails shall be accepted.

If it is not satisfactory a further tensile test shall be made from each of the other two casts in the same lot of rails.

For each cast not meeting the test, the bars P shall be rejected.

A further tensile test shall then be taken from each of these casts on a length of 300 millimetres (11 13/16 inches) selected from the top of one of the bars P rejected.

If this test is unsatisfactory, the casts in question shall be finally rejected.

Paragraph 3 : *Hardness test.* — No dimension as to the diameter of the impression is laid down, as this test is only required for information.

The hardness test shall be carried out at most on three samples from each cast.

### ART. 8. — Branding of rails.

The rails shall bear, on one face of the web, in relief from the rolls and thereby reproduced once each revolution of the rolls :

1) The trade mark of the maker;

2) The month and the two last figures of the year of manufacture; the marks for the month can be made by dots, bars or Roman figures;

3) The process of manufacture — Thomas, Bessemer, or Martin — to be indicated by the letters T., B., M.;

4) The letter or figure indicating the type of rail;

5) An arrow pointing towards the extremity of the rail corresponding to the top of the ingot;

6) The number indicating the minimum resistance laid down (this number can if desired be stamped hot if the works prefer).

For example: A rail marked 65 — Works IIII — 19 — T — S. 12 — would indicate a rail made of Thomas steel of 65 kgr. quality standard type 46 kgr. (92.73 lb. per yard) shewn

by the figures S. 12, made in April 1919.

In addition, on each rail shall be stamped hot, on the side of the web carrying the marks rolled on the rail at a distance of about 1 metre (3 ft. 3 3/8 in.) at the end corresponding to the top of the ingot, the number of the cast and that of the ingot. Beside these numbers the letter H shall be stamped when the rail is the one made immediately after the top discard of the ingot, and the letter P on a rail taken from the bottom of the ingot, and, when necessary, a number corresponding to the minimum resistance specified.

Rails of usual length which do not bear these marks stamped when hot shall be rejected.

When the rails have been finished, the marks, the cast and ingot numbers, and the letters H or P shall be again stamped when cold on the nearest end so that they can always be seen when the rails are stacked.

Each top and bottom discard shall be, like the rails, marked when hot with the number of the cast and that of the ingot.

The rails accepted shall be stamped at both ends with the inspector's stamp.

All rails rejected shall be stamped on the head to the right of the cast number with agreed marks which cannot be obliterated to prevent them from being again offered for inspection.

### Art. 9.

### Guarantee. Makers' responsibility.

Paragraph 1 : *Guarantee.* — The maker guarantees the rails for ten years from the date of manufacture. In all cases the sum of money withheld against the guarantee shall be paid at the end of six years.

In the case of any rail during this period breaking either when being handled, or when in place, or becoming defective otherwise than by ordinary wear, or in which any defects overlooked during the inspection should be noticed, the supplier shall be required to pay compensation equal to the value of the rail in question calculated on the price of the last order passed by the Railway for similar rails of at least 1 000 tons immediately before the breakage occurred.

The Railway Company shall, provided the order so states, determine from test pieces to be sent to the maker, the proportion of rails to which the guarantee shall apply.

Any rails which, owing to their special use, after delivery have to be worked up, either hot or cold, at points where breakage or defects subsequently shew themselves shall not be subject to a payment of this indemnity unless defects due to faulty manufacture are found.

Broken or damaged rails shall remain the property of the Railway Company.

When rails are to be used for railways in course of construction, the order shall contain special stipulations as regards the beginning and duration of the guarantee.

Paragraph 2 : *Patent rights.* — Any patent rights that have to be paid to inventors will be paid by the maker who will guarantee the Railway Company against any claim.

Paragraph 3 : *Cost of test, inspection, etc.* — The installation of test appliances, their upkeep, and the labour and other costs incurred during reception with regard to the tests and analyses mentioned above, shall be at the sole charge of the maker.

Paragraph 4 : *Responsibility of the maker.* — The supervision carried out by the inspector at the works, the examination or tests, and the acceptance of the manufactured rails shall not, in any case, reduce the responsibility of the maker, as he will remain entirely responsible for the rails until the expiration of the period of guarantee.

[ 656 .254 ]

# Highway safety promoted by mechanical traffic control methods,

By Arthur H. BLANCHARD,

PROFESSOR OF HIGHWAY ENGINEERING AND HIGHWAY TRANSPORT, UNIVERSITY OF MICHIGAN,

CONSULTING ENGINEER, MICHIGAN STATE HIGHWAY DEPARTMENT.

(*Bulletin of the Permanent International Association of Road Congresses, No. 43.*)

Before considering the specific conditions in connection with which mechanical traffic control methods should be used to promote the safe use of highways, it is well to have in mind the general status of highway accidents. A bird's eye view was presented in the Report of the Committee on « Statistics » submitted at the First National Conference on Street and Highway Safety which was held under the auspices of the Hon. Herbert Hoover, Secretary of Commerce, in Washington, D. C., in December 1924. Pertinent abstracts from this report follow :

« In 1923 the loss in the United States due to street and highway accidents amounted to 22 600 human lives, 678 000 serious personal injuries and $600 000 000 economic loss, an increase of 80 % in the past seven years. About 85 % of these accidents were due to automobile traffic.

**Highway fatalities in the United States.**

| — | Estimated fatalities. | | Rate per 100 000 population. | |
|---|---|---|---|---|
| | 1923 | 1922 | 1923 | 1922 |
| Train grade crossing accidents (1). . . . . | 2 268 | 1 810 | 2.0 | 1.7 |
| Street car accidents. . . . . . . . . . . . | 2 006 | 1 748 | 1.8 | 1.6 |
| Automobile accidents. . . . . . . . . . . | 16 452 | 13 676 | 14.9 | 12.5 |
| Motorcycle accidents. . . . . . . . . . . | 336 | 314 | 0.3 | 0.3 |
| Injuries by other vehicles . . . . . . . . | 1 559 | 1 655 | 1 4 | 1.5 |
| Total. . . | 22 621 | 19 203 | 20.4 | 17.6 |

(1) Grade crossing figures from Interstate Commerce Commission.

**Motor vehicle fatalities compared with registration of motor vehicles in the United States.**

| YEAR. | Total number motor vehicle deaths. | Total registration of motor vehicles. | Number motor fatalities per 100 000 motor vehicles registered. |
|---|---|---|---|
| 1917 . . . . . . | 9 184 | 5 104 321 | 190 |
| 1918 . . . . . | 9 672 | 6 146 617 | 160 |
| 1919 . . . . . . | 9 827 | 7 565 446 | 130 |
| 1920 . . . . . . | 11 358 | 9 231 941 | 123 |
| 1921 . . . . . . | 12 500 | 10 463 295 | 119 |
| 1922 . . . . . . | 14 000 | 12 238 275 | 114 |
| 1923 . . . . . . | 16 000 | 15 092 177 | 106 |

In this discussion, only one problem will be considered, namely, safety devices and regulations at railroad grade crossings. This topic has been selected as a consideration of its complex features introduces most of the fundamentals of the utilization of mechanical control methods or methods for other road conditions requiring signals and special regulations to promote the safe use of highways by the motor vehicle driver.

In considering the problem of traffic control methods by mechanical devices, it is advisable to glance for a moment at the methods which are available for reducing the number of accidents at railroad grade crossings. Engineers and investigators in the railway fields propose a program which consists of four lines of action.

First, the elimination of grade crossings in congested areas as rapidly as it is financially practicable at the joint expense of the railways and the local communities.

Second, the increase of protection at grade crossings as much as is practicable. Under this head are considered methods which are applicable to a great many existing railroad crossings at the present time, such as increasing the distance of vision along the tracks from the highway, by the removal of obstructions of one kind or another, the changing of grade approaching railroad crossings, and relocations in a great many cases to obviate dangerous grade crossings.

Third, to place warnings at the approaches of all crossings.

Fourth, the education of the motorist relative to the danger of careless driving across railroad grade crossings.

Contact with the first item on this program is met in discussions of this problem through the public press and at various organization meetings of laymen, the contention being generally made that the only solution is the immediate elimination of all grade crossings. Is this solution practicable ? At the end of 1921 there were 252 507 grade crossings. In 1922 there were 705 eliminated and 4 437 were added, giving at the end of the year a total of 256 239. The cost during 1922 was $70 000 000 or an average cost for the elimination of one grade crossing of $ 100 000. Taking as an estimate $75 000 for the elimination of a grade crossing, the bill for the elimination of all the grade crossings existing on 1 January 1923, would be $19 500 000 000. A contemplation of these figures indicates that it is absurd to de-

pend solely upon elimination of grade crossings for the solution of the problem.

There is one phase of this matter that deserves more than casual consideration. Reference is made to a timely recommendation by A. H. Rudd, chief signal engineer of the Pennsylvania Railroad System, as contained in the following statement :

« The Pennsylvania Railroad System in 1923 killed two passengers in train accidents; in 1922 it killed six, five of them in one collision on a road that had been recently taken over and had no block system. Last year the Road didn't kill one, and in that time, — three years, eight passengers killed — there were 711 people killed at highway crossings.

« The Pennsylvania Railroad has been ordered to install automatic train control on three passenger engine divisions. It will cost in the neighbourhood of $6 000 000. To equip our whole system with train control would cost $115 000 000. For this sum we can protect 57 000 crossings with flashing lights, indicating the approach of the train, the new signal recommended by the Signal Section of the American Railway Association, and still have $80 000 000 left for separation of grades, if we didn't have to put in train control (and if we had the money). »

The present program of the Interstate Commerce Commission to force the installation of automatic train control should receive the careful consideration of every citizen because of the immense amount of capital involved, which, in the opinion of many railroad and highway officials, could, from the standpoint of the safety of the people as a whole, be much more effectively expended in the elimination of grade crossings and installation of signals at all crossings.

The next phase of this subject is with reference to traffic control relative to which there has been a wide diversity of opinion between highway officials and motorists on the one hand and railroad officials on the other. Railroad officials have been contending, in many cases, for a full stop law which would mean that at every one of the 260 000 railroad crossings in the United States vehicles must stop before crossing the track. The effects of a full stop law should be given thorough consideration, not only from the standpoint of safety but also from the viewpoint of the economics of transportation.

Take, for example, a highway which has a daily traffic of 10 000 vehicles and which is crossed by a railway carrying one passenger train with an average of 30 passengers each way per day. An examination of the traffic on that highway might indicate the following conditions which are based upon personal observations. In travelling a highway of this type for a distance of eight miles, 15 groups of massed automobiles, ranging from 10 to 32 vehicles in each group, were passed. Contemplate the danger from collisions and the delay involved in requiring each one of these vehicles to come to a full stop before it crosses the railroad track. Such a regulation would mean, based on a conservative estimate, that in one day 20 000 people would be delayed for the benefit of 60 train passengers. There are at the present time many railroads of this character in the United States.

From a broader viewpoint, a universal full stop regulation would mean, assuming one grade crossing in every ten miles of highway and that each motor vehicle travels twenty miles per day, that there would be not less than 35 000 000 vehicle stops at railroad crossings each day throughout the United States.

This subject was discussed during two sessions at the National Conference on Highway and Street Safety. The following conclusion was adopted which, it is believed, all will agree was based on sound common sense principles : « Properly designated State commissions

should be empowered to designate dangerous grade crossings at which motorists must stop. »

Now what is the other side of this full stop regulation ? There is a growing opinion among highway officials and some railroad officials that there are conditions under which it is advisable to have a full stop provision which has not been outlined as yet, namely to have trains come to a full stop before crossing a highway. Within the next year there is little doubt but what this provision will be placed in operation on many short line railroads carrying perhaps a total of 300 passengers on trains as against 20 000 or more carried on the highway during a given day. In other words, in many cases it will be advisable that a transportation survey be made of a railroad grade crossing to ascertain the traffic on the railway, the traffic on the highway, and the physical conditions which surround the crossing from the standpoint of visibility of the tracks from the highway.

Those railway officials, who in recent years worked so strenuously for the general adoption in our Legislature of a full stop provision, admit that the regulation proposed by the Committee on « Traffic Control » of the Hoover Conference and adopted by that Conference, to the effect that, unless a State commission has designated a grade crossing as one at which motorists must stop, « vehicles should not be permitted to exceed a speed of 15 miles per hour when approaching within 100 feet of a grade crossing », has never been given a chance to demonstrate its value. In connection with that recommendation, which is based upon the practical operation of motor vehicles under control, it is of interest to cite the following opinion of Supreme Court Justice Charles Van Kirk of the State of New York.

« Having provided for a disc sign and how and by whom it shall be placed the statute in peremptory language provides: It shall be the duty of the driver of any vehicle using such a street or highway and crossing to reduce speed to a safe limit upon passing such sign and to proceed cautiously and carefully with the vehicle under complete control.

« It is our view that if the drivers of automobiles obey this statute to its letter and its intent, seldom if ever will injuries be suffered at grade crossings. The price of safety by obedience to this statute means no more than three or four seconds of time, a small price for a life, and in any event we believe the legislature was more interested in preserving life and limb than in preserving the right to recover damages for life and limb lost.

« The safe limit of speed in approaching a crossing is that speed at which the driver of an automobile, as he arrives at a point where he can see an on-coming train when it is near enough to render crossing ahead dangerous, can stop his car if necessary before he reaches the track. It is futile to look when one cannot see. If he cannot see without stopping he must stop. »

Those who are in favor of adopting a reduced speed limit at grade crossings, also contend that its value is dependent upon its enforcement. That does not mean that an officer must be present at every railroad grade crossing but it does mean that, if officers will arrest persons who do not comply with a statute of this character and if such arrests are properly and widely advertised in the public press, a vast majority of the operators of vehicles soon will acquire the habit of observing such laws.

Other methods of control will be considered under the general subject of mechanical methods. Gates will be passed by as there is a decided difference of opinion among railway officials as to the value of the utilization of gates at railroad grade crossings. It is self-evident, however, that gates and flagmen may be used effectively at many danger-

ous crossings on highways subjected to intensive traffic.

A phase of control by mechanical methods has been promoted in certain quarters. Some have advocated the construction of humps or corrugations in the roadway surface in order to force operators to reduce speed. Others have urged the installation of various devices which will require cars to slow down their speed because of obstructions placed in the highway, causing vehicles to be diverted from the regular path. Some of these include two turns marked on the highway by curbs which a vehicle must pass around before reaching a grade crossing. While there may be a difference of opinion regarding the value of these methods, it is believed that the following conclusion presented by the Committee on « Construction and Engineering » headed by Hon. Frank Page, Chairman of the North Carolina State Highway Commission, and adopted by the Hoover Conference is sound: « Roughness in the pavement or other conditions at or near the tracks, which tend to divert the attention of the motorist, should be avoided. » The Committee report described the « conditions » mentioned in the conclusion as follows :

« Transverse ridges in the road, zigzag turns and various other expedients designed to force the motorist to reduce speed at railroad crossings have proved ineffective and are not recommended. On the contrary, your Committee believes the operation of the motor vehicle, particularly on and in the immediate vicinity of the tracks, should be made as simple and easy as possible so that the operator can apply himself to watching for approaching trains. Very much can be done along these lines for a relatively small expenditure, and the dangers of many crossings can thereby be greatly reduced. Frequently where the railroad is on an embankment the highway is carried up to the level of the tracks by a short steep grade which breaks sharply at the track itself, causing danger of stalling. Such approaches should be extended and provided with easy vertical curves or level places so that the motorist can stop and hold his car easily within ten feet of the railroad if he discovers a train coming. Short sharp descents to the tracks should likewise be cut away to easier grades to lessen the likelihood of motorists being unable to stop near the tracks, or of being rammed from behind and driven upon the tracks. »

What mechanical method may be employed ? In discussing this subject, it is desirable to present definite recommendations relative to the meaning of different light colors. The Hoover Conference adopted the following conclusions : « For signs and signals, both luminous and nonluminous, the following color indications are recommended, and these colors should not be used for any other purpose : *Red* for « Stop »; *green* for « Proceed »; *yellow* for « Caution », as at curves. » This subject may be considered from two standpoints, first, mechanical devices which may be employed during daylight, and second, those which may be employed either at night or during both the hours of daylight and darkness.

During daylight it is self-evident that the standard disc signs at the side of the pavement usually are effective as well as markings on the pavement. Of course there are conditions under which both of these may not function. As a general proposition, the sign if properly placed and at a height of visibility will be effective except when it is covered by snow or ice. Markings on the highway or pavement, of course, are not effective when the pavement is not clean or is covered with snow or ice and dirt. To indicate the approach of trains during daylight hours, the automatic wigwag signals have proved effective, provided they are efficiently maintained.

The most difficult and complex phase

of this problem is in regard to the methods by which the highway officials and engineers and the railroads can give adequate warning to motorists approaching railroad crossings during the night.

What methods may be utilized at crossings designated as dangerous ? There is no question but what it will be desirable, as rapidly as practicable, for railroads to install *at all crossings* signals of the type advocated by the Committee of Signal Engineers of the American Railway Association, namely, the showing of intermittent lights, red in color, to indicate the approach and passage of trains at given crossings and giving a definite signal to the operators of vehicles that they must come to a full stop.

There may be a difference of opinion as to the method to be employed to give constant notice that a crossing has been designated as a full stop crossing by a State commission. There is no question but what a red light should be employed. The difference of opinion will come as to whether it should be a clear continuous light or a flashing light. In this connection, it should be borne in mind that the education of the public relative to the utilization of uniform signals is of paramount importance. Otherwise there is a tendency for motorists to become callous and neglect the warning which it is intended should be indicated by a given type of signal. In other words, if an intermittent light is to be used by the railroads to indicate an approaching or passing train, the utilization of a flashing red light would be of doubtful expediency. The position of such a light indicating full stop should be near the railroad tracks. To provide for maximum safety, the railroad signal of intermittent lights, red in color, should be installed to indicate the approach and passage of trains and a continuous non-flashing red light, having a lens with the standard black cross an R R painted on its face, should be used to signify to the motorist that he is approaching a full stop railroad crossing. This type of light also be employed at full stop crossings in cases where the railroad has not erected train approach signals.

In the case of grade crossings which are classed among those at which speed should be reduced, a continuous yellow warning signal light, having a lens with the standard black cross and R R painted on its face, should be placed at a distance of 300 feet to give the necessary warning. As previously stated, the regulation is that within a distance of 100 feet from the railroad the motor vehicle operator should reduce the speed of his vehicle to 15 miles per hour. Such a law may be easily complied with if the light is installed at 300 feet from the railroad crossing. Of course, the railroad intermittent red light signal should be erected at the crossing to indicate the approach and passage of trains. Without lights or illuminated signals, it appears that it is placing a degree of responsibility on the motorist which is unreasonable as it is with extreme difficulty that the ordinary non-illuminated signs are visible to the travelling public at night.

The endeavour has been made to base these recommendations relative to mechanical methods on the principles of reasonable traffic control. They have been proposed in the interest of the safety of a very large percentage of the 17 000 000 owners of motor vehicles, rather than to penalize this vast majority for the foolhardy acts of a small minority of operators who race an express train to a crossing, crash through a gate, or collide with a train and pass on into eternity.

[ 621 .133.3 (.73) ]

# McClellon water-tube boiler locomotives.

Figs. 1 to 9 pp. 1014 to 1019.

(From the *Railway Mechanical Engineer.*)

In 1916 the New York, New Haven & Hartford, placed in service two Mikado type locomotives fitted with McClellon water-tube fireboxes. These two boilers met wit indifferent success. The original design developed some weaknesses in the details of its construction but showed that its fundamental principles were mechanically sound and that with a modification of the details that were giving trouble, the boiler would probably give satisfactory service. Unfortunately, Mr. McClellon died at this time, just as the boiler had demonstrated its possible practicability.

W. L. Bean, mechanical manager of the New York, New Haven & Hartford, feeling confident that this type of firebox construction possessed advantages over the ordinary radial-stayed firebox, undertook to study fully and to correct the troublesome features which had become apparent in actual service. These changes were made in 1920 to the two original boilers, which are still in service. In 1924, having 10 Mountain type locomotives on order with the American Locomotive Company, it was decided to equip one of these locomotives with the McClellon firebox, embodying such changes in the structural design as had already been made in the two existing boilers, and including further modifications which were felt might prove to be advantageous.

Realizing that this design of boiler is particularly adaptable to high pressures, one of the modifications made in the new locomotive was to increase the boiler pressure to 250 lb., which, with the use of a 70 % limited cut-off, would give greater steam economy. Viewed from the standpoint of the present design, it is of very simple construction and well adapted to meet and properly withstand the stresses inherent in locomotive service.

The character of the construction is clearly shown in the illustrations. It will be seen that the ordinary parallel sheet construction of the back head, sides and combustion chamber are replaced with walls of water tubes. The roof and crown sheet area in the conventional type is replaced with a section formed of three longitudinal drums extending the complete length of the firebox and combustion chamber and attached at the front end to the rear tube sheet. These drums are in contact with each other throughout their length and are so flattened at the contact areas as to permit the largest possible steam and water space. They are prevented from separating by screw rivets that keep the flat sections in continuous contact throughout.

Combustion chamber and side tubes are 4 inches in outside diameter, swedged to 3 inches at the ends, with walls 1/4 inch thick. The back head 'ubes are 2 inches in outside diameter for their entire length, with walls 3/16 inch thick. All tubes are rolled and beaded at the top ends in the drums, but are rolled and flared in the mudring at the

Fig. 1. — New York, New Haven & Hartford 4-8-2 type locomotive with McClellon firebox.

Fig. 3. — The construction of the back boiler head. — Note the pads on the channel braces to which the heavy plate cross member is bolted.

Fig. 5. — Interior of the firebox before the walls are closed.

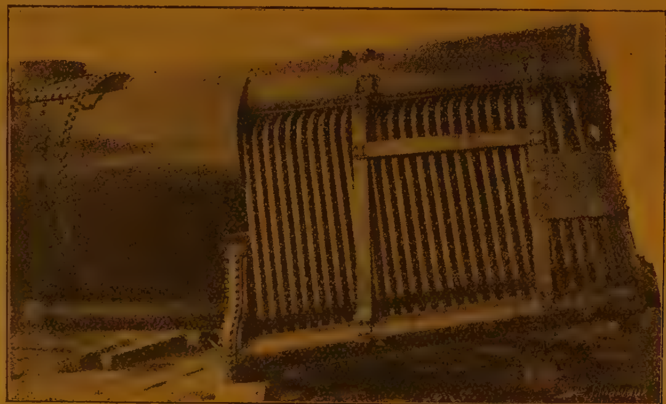


Fig. 4. — Side of the completed firebox.

bottom ends. The arch tubes are conventional in size but at the top the ends are turned up into the drums and rolled and beaded. All tubes entering the drums are on the drum radius and perpendicular at the point of entrance.

To accommodate proper seating of the tubes in the mudring, the top wall is flattened inside and outside. The outside of the bottom wall also is flattened. Through it holes are tapped opposite each tube to permit the initial installation of tubes and such inspection and maintenance as may be necessary. These holes are closed with plugs, all of which do not constitute washout plugs but on the contrary are so-called « construction plugs ».

There is a slight clearance between all tubes forming the firebox construction in order to permit of easier installation. Lagging and protection is applied on the sides and back head, outside of the tubes, to which reference will be made later. All back head tubes are staggered at the entrance into the drums because of the relatively restricted section forming the crown, as compared with the length for tube spacing available in the mudring.

The illustrations given are all taken from locomotive 3 500, which is equipped with a Duplex stoker. Several of the back head tubes are bent away from their normal position in order to permit entrance of the stoker distributor tubes. This construction is used where the Duplex stoker is applied but is not used when the Standard stoker or similar types are applied.

The fire door opening is a combination water-leg and water-tube construction. The section below the door is of a conventional stayed construction. It is made up in three pieces : a single inverted U-shaped piece flanged and riveted to the mudring, with the ends closed by semi-circular sheets bent and riveted in place. The sides of the door opening are formed by large tubes joining the stayed section at the bottom and connected near their upper ends by the top door member which is formed rectangular in section from round tubing. Regular 2-inch tubes are carried from the top member of the door frame up to the drums in the same manner as the main back head tubes, with plugs located on the underside of the rectangular member opposite tube holes. The large side tubes are capped at their top ends with steel castings, welded in place, into each of which 2-inch tubes are applied and carried up to the drums.

One of the troubles with the original construction was lack of provision for any column action to take the stresses between mudring and drums independently of the tubes. This situation is avoided by a series of braces between the mudring and the drums so arranged as to form, in combination with the drums and mudring, a hollow box girded type construction. This relieves the tubes of any duty other than that of steam and water containers under pressure. Shocks incident to locomotive service are transmitted through this bracing construction and kept away from the tubes, so that they remain continuously tight, even under severe and unusual operating conditions. The braces at the sides of the firebox are of channel section secured with fitted bolts to the mudring and to castings applied to the drums. The braces are seated against shoulders so that the bolts are relieved of shear. Horizontal members of rectangular section connect the main side braces to give additional stiffness.

The arrangement of bracing, being free from triangulation, permits the necessary free longitudinal movement of drums relative to the mudring resulting from temperature differences between the mudring and crown sheet areas. Similar construction is employed at the back head. The top connections of the back head braces into the saddle castings on the drum heads are so arranged

as to permit inspection and attention to the seams between drums and drum heads. An arch effect is obtained through the use of the diagonal braces which connect the column members to the center drum.

A back head belt of wide plate section is bolted to the back head braces and carried around the corners of the firebox to the rear side braces. This not only forms a part of the back head bracing, but serves as a foundation on which all of the back head and cab fittings are applied.

The throat sheet at the front end of the firebox is generally similar to the ordinary throat sheet in conventional boilers, except that it is vertical and is arranged to give greater accessibility for washing out. The back plate of the throat is flanged outwardly to receive the front ends of the hollow mudring, and opposite the mudring connections, the front throat sheet is fitted with hand hole plates similar in constuction and arrangement to those used in marine and stationary practice. The top points at the sides of the throat are fitted with caps and vented through copper pipes which permit the escape of steam into the steam space in the central drum. Figure 6 shows a detail of this construction.

The combustion chamber, like the fire-

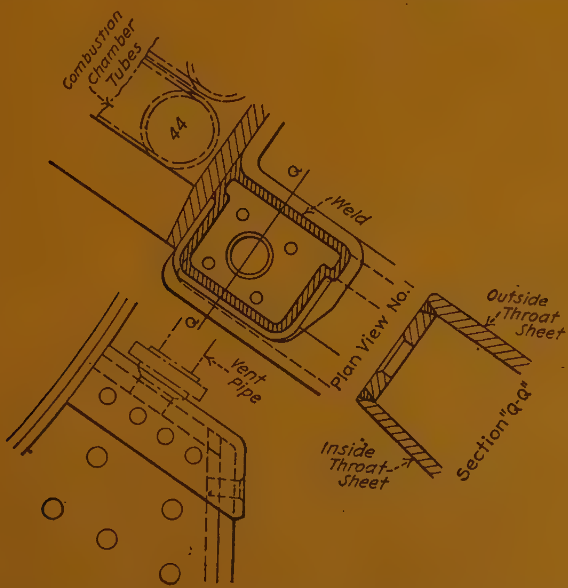



Fig. 6. — Method of closing throat sheet corners. A plate is first welded in the opening, the lap of the sheets at the end of the throat is smoothed by welding and scarfing and the flanged cap fitted in place hot, after which it is secured by screw rivets and welded to the dry shell and to the inside plate at the edges of the vent opening. The opening is then reamed and the studs applied.

box, is of water-tube construction, but it is encased in a dry shell extension of the third barrel course. This course provides the structural strength for the connection of the firebox and the barrel portions of the boiler. It will be seen in the photographs that at the top it is securely riveted to the two outside drums throughout the length of the combustion chamber and that the inside

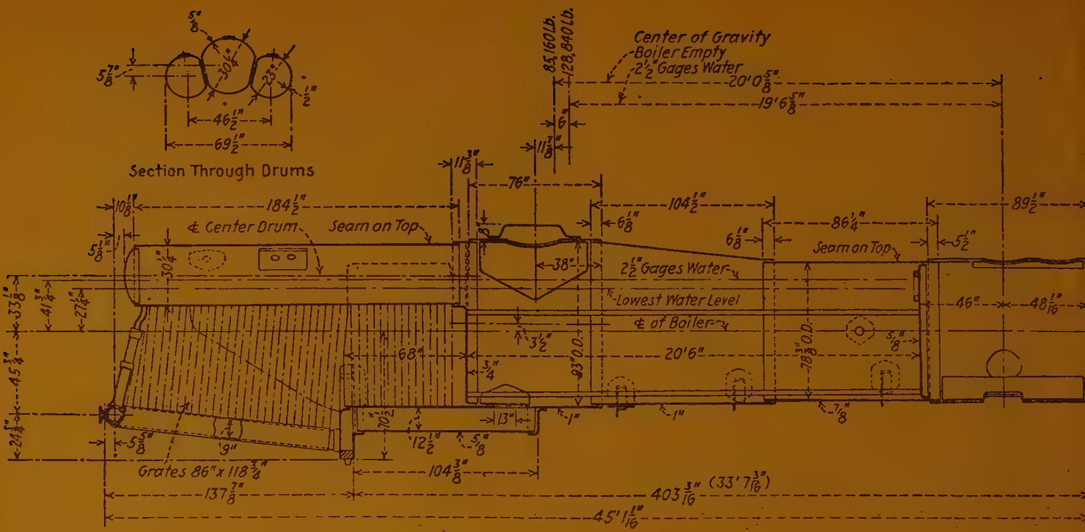



Fig. 7. — Sectional elevation of the McClellon firebox and boiler.

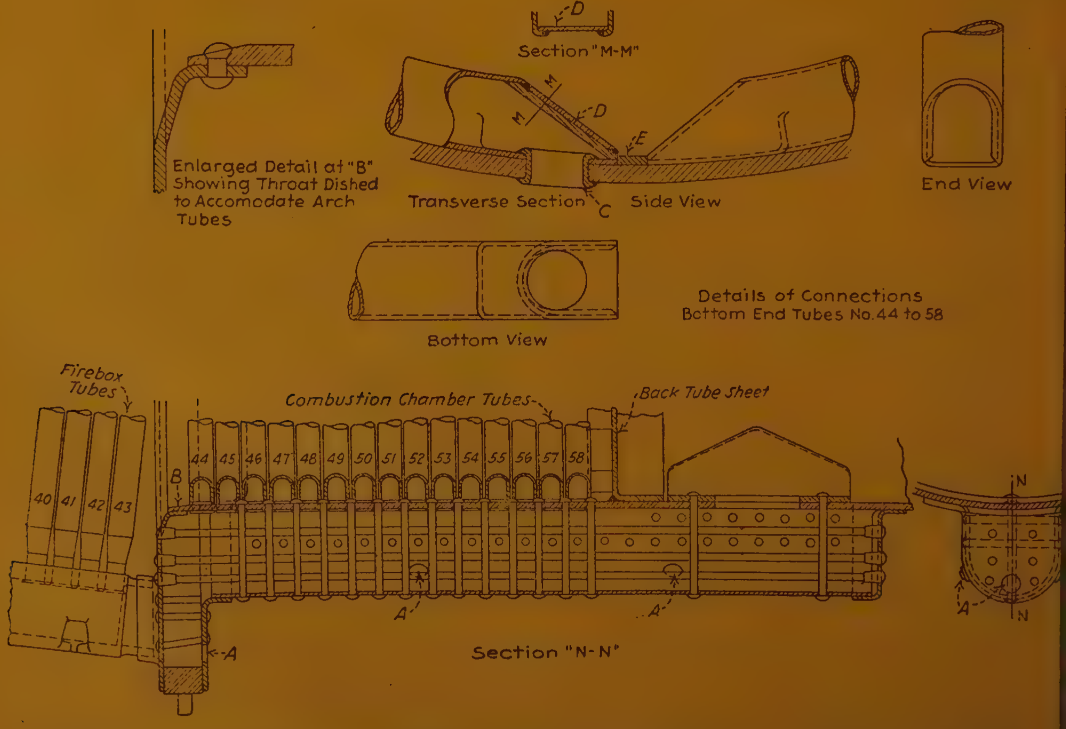



Fig. 8. — Circulating trough and combustion chamber tube construction. — Washout plugs as shown at
circulating nipple at C; combustion chamber tube end at D, and space blocks to relieve nipples of shearing, a

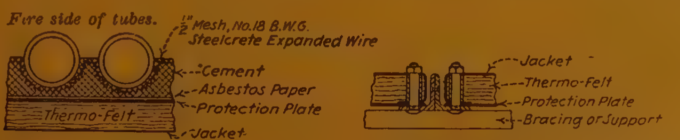
and outside throat sheets are riveted to it at the bottom. The rear tube sheet is also riveted in this course with the flange extending forward into the water space. It is flanged in the opposite direction to receive the front ends of the three drums which form the top of the firebox, no flanging or swedging of the drums being required. To permit the caulking of the tube sheet flanges at the sides of the two outside drums where the dry shell overlaps the flanges, a recess has been cut in this shell. The opening thus made into the combustion chamber is closed with a fitted cover plate, to prevent the escape of gases into the lagging.

To permit the transfer of water from the barrel of the boiler to the firebox and combustion chamber a circulating trough is riveted on the outside of the third course at the bottom. The front end extends ahead of the tube sheet and opens through the shell into the boiler, while the rear end is riveted into a flanged opening in the outside throat sheet.

All combustion chamber tubes enter the side drums at their upper ends in line with the firebox tubes. The bottom ends of all except the rear tube on each side open to the circulating trough through holes in the dry shell. The rear tubes open directly into the throat sheet water space.

The attachment of the combustion chamber tubes to the circulating trough involves a unique type of construction, which is shown in detail in figure 8. The tubes are flattened and curved to fit the dry shell at the bottom and their ends are cut away on an angle. A hole through the flattened wall of the tube fits over a nipple, applied through the hole in the dry shell and rolled, beaded and welded, before the circulating trough is in place. The upper end of the nipple is rolled, beaded and welded in the tube, working through the open end of the tube. The end of each tube is closed by plate welded in place, over which the edges of the tube are flanged and welded. A space block is applied between the right and left tubes of each pair to relieve the nipples of shearing action.

The lagging on the outside of the firebox is composed of a protection plate, insulation and jacket. The lagging is made up in sections with each panel self-contained in order to permit the removal of lagging in sections without the necessity of wholesale stripping for access to tubes and other parts. The




*Sectional view of lagging over firebox tubes.*

*Section showing method of fastening protection plate, thermo-felt and jacket as a single unit at edges of panels.*

Fig. 9. — Details showing the construction of the firebox enclosing wall and the method of attaching the lagging and jacket in panel units, to a framework of angles supported on the firebox braces. The usual type of asbestos lagging and jacket are applied over the top and ends of the drums.

lagging is applied after the tubes have been covered with an asbestos cement.

No detailed study has been made of circulation in this boiler, but observations of the bare boiler, fire-up during construction and without any lagging or insulation whatever, indicate a very uniform warming up of the entire boiler

from front end to back head without the usual unequal heating normally experienced in the radial-stayed construction. The time required to fire up the cold boiler is only two-thirds of the time usually required with the radial-stayed construction. There is a very noticeable scouring action through the tubes of the firebox and combustion chamber, undoubtedly due to the rapid and positive circulation and indicated very definitely by lack of mud and scale in the mudring and tube area. Most of the mud accumulated is relatively soft and is deposited in the trough section. In other words, the dead corners of the conventional boiler and firebox are absent in the McClellon construction.

The freedom from unequal heating, momentary distortion of the firebox while warming up, more rapid circulation and absence of dead corners that give rise to mud and scale accumulation all indicate a better type of boiler construction than normally used. The time required to wash one of these boilers is only about one-half or two-thirds of the time required for the ordinary boiler. Stresses due to unequal temperature conditions are greatly reduced as indicated by considerably less maintenance on the firebox and combustion chamber portion of the boiler. Both running and back shop repairs are less on the boilers with this type of firebox than on those with the conventional type of firebox. The ten years' experience of the New Haven indicates that the maintenance cost is reduced about one-half, and there is also a considerable increase in the time available for service.

There is greater potential capacity in this type boiler when the locomotive is running before low steam conditions are experienced from any cause than is the case with the conventional locomotive boiler.

Table I.

*Comparison of the principal characteristics of the two locomotives tested :*

| | Engine 3324 | Engine 3500 |
|---|---|---|
| Type | 4-8-2 | 4-8-2 |
| Boiler | Firetube | Firetube |
| Firebox | Radial-stayed. | McClellon. |
| Weight on drivers | 230 500 lb. | 243 500 lb. |
| Total weight, engine and tender | 518 800 lb. | 549 000 lb. |
| Boiler pressure | 200 lb. | 250 lb. |
| Cylinders | 27 by 30 inches. | 27 by 30 inches. |
| Maximum cut-off | 85 %. | 70 %. |
| Diameter of driving wheels | 69 inches. | 69 inches. |
| Tractive force | 53 900 lb. | 63 390 lb. |
| Factor of adhesion | 4.28. | 3.81. |

The arrangement of outside throttle and superheated steam on most of the auxiliaries is in keeping with present day practice. An Elesco feedwater heater and Duplex stoker are applied, the front end is fitted with Okadee hinges and the air operated whistle uses superheated steam.

When this locomotive was built as many dimensions and characteristics as possible were kept the same as the conventional engines built at the same time from the U. S. R. A. light Mountain type design for fast freight service. Thus, all tests could be made on a comparable basis as between the McClellon firebox

and the standard locomotive, thereby eliminating variables that would tend to influence conclusions. Consequently, the cylinder and wheel sizes, grate area, heating surface, superheater surface, etc., were all kept at the same values and the changes in the McClellon equipped locomotive were confined to the firebox arrangement, boiler pressure, valve events and, to some extent, the weight on drivers. Virtually the same limitation on axle loads held good for the McClellon equipped engine as were imposed in the case of the standard type.

After receipt from the builders in 1924, this locomotive, road No. 3500, was placed in regular freight service and was later subjected to extensive tests in comparison with one of the standard engines, road No. 3324. The tests with both engines were conducted over the same division, from New Haven, Conn., to Providence, R. I., a distance of 113 miles.

TABLE II.

*Dimensions, weights and proportions of engine 3 500, equipped with McClellon firebox :*

| | |
|---|---|
| Type of locomotive | 4-8-2. |
| Service | Freight. |
| Cylinders, diameter and stroke | 27 by 30 inches. |
| Valve gear, type | Southern. |
| Valves, piston type, size | 14 inches. |
| Cut-off in full gear, % | 70. |
| Weights in working order : | |
| On drivers | 243 500 lb. |
| On front truck | 59 500 lb. |
| On trailing truck | 57 000 lb. |
| Total engine | 360 000 lb. |
| Tender | 189 000 lb. |
| Wheel bases : | |
| Driving | 18 ft. 3 in. |
| Total engine | 40 ft. 10 in. |
| Total engine and tender | 76 ft. 5 1/2 in. |
| Wheels, diameter outside tires : | |
| Driving | 69 inches. |
| Front truck | 33 inches. |
| Trailing truck | 43 inches. |
| Boiler : | |
| Type | McClellon. |
| Steam pressure | 250 lb. |
| Fuel, kind | Bituminous coal. |
| Diameter, first ring, outside | 78 3/8 inches. |
| Firebox, length and width | 120 by 85 inches. |
| Height mud ring to crown sheet, back | 63 3/4 inches. |
| Height mud ring to crown sheet front | 98 3/4 inches. |
| Arch tubes, number and diameter | 4 — 3 inches. |
| Combustion chamber length | 68 inches. |
| Firebox tubes, number and diameter : | |
| Sides | 58 — 4 inches. |
| Back | 28 — 2 inches. |
| Combustion chamber | 30 — 4 inches. |
| Tubes, number and diameter | 201 — 2 1/4 inches. |
| Flues, number and diameter | 40 — 5 1/2 inches. |
| Length over tube sheets | 20 ft. 6 in. |
| Grate area | 70.8 square feet. |
| Heating surfaces : | |
| Firebox : | |
| Drums | 81.8 square feet. |
| Back section | 46.5 — |
| Side and back tubes | 187.0 — |
| Combustion chamber tubes | 115.8 — |
| Arch tubes | 27.0 — |
| Total | 458.3 — |
| Tubes | 2 469 — |
| Flues | 1 134 — |
| Total evaporative | 4 061 — |
| Superheating | 1 009 — |
| Comb. evaporative and superheating | 5 070 — |
| General data estimated : | |
| Rated tractive force, 70 % cut-off | 63 390 lb. |
| Cylinder horsepower (Cole) | 3 090. |
| Steam required per hour (Cole) | 58 710 lb. |
| Boiler evaporative capacity per hour (Cole) | 63 072 lb. |

Table 1 gives a comparison of the principal dimensions of the two locomotives tested. It will be seen that although both have the same cylinder dimensions, engine 3500 had the advantage of 50 lb. per square inch in steam pressure, with a consequent higher tractive force of about 17.6 %. This higher tractive force is obtained with an increased weight on drivers of only 6 %, or in other words, with a reduced factor of adhesion. The locomotive required no more care in handling than the other engines with the higher adhesion factor because of the smoother torque resulting from the relatively shorter cut-offs.

The first tests with engine 3500 were conducted to establish the maximum tonnage which the engine was capable of handling. Starting with 4 000 equated tons on a 75-car basis, the load was increased to 6 547 equated tons. The engine started and accelerated this train without difficulty on a 0.142 % grade. Tests with greater tonnage were prevented by lack of available tonnage because of the coal strike and the maximum capacity of the locomotive is still undetermined.

The results of the tests show that engine 3500 hauled 3.2 % more tonnage than engine 3324, maintaining the same average speed and the same running time over the division, while working at a 16.5 % shorter cut-off and at the same time used 10.7 % less coal than did engine 3324. This resulted in a decrease of 15.1 % of coal per 1 000 gross ton-miles. No material difference in superheat was noticed in the tests on the two locomotives.

Because of the higher boiler pressure and limited cut-off of engine 3500, a saving of 5 % in pounds of water per dynamometer horsepower-hour was obtained, which, coupled with the 12.0 % increase in evaporation per pound of dry coal, resulted in a decrease of 18 % in dry coal per dynamometer horsepower-hour. The McClellon boiler of engine 3500 shows an increased efficiency of 9.4 % over the standard boiler of engine 3324, while there was an increase in overall thermal efficiency of 15.5 % in favor of engine 3500.

The results of this service and the tests were so satisfactory and so conclusively demonstrated the advantage of the McClellon boiler that, when ten new engines were recently purchased for the road, there was no question or discussion as to the type of boiler to be used. The McClellon water-tube boiler was ordered to be placed in all of them.

[ 656 .256 (.42) ]

# Safety and economy in railway operation.

## Enterprise of the Cheshire Lines Committee.

### SIGNAL BOXES ELIMINATED BY TRANSIENT TRACK CIRCUIT INSTALLATIONS.

Figs. 1 to 5, pp. 1023 to 1029.

(*Modern Transport.*)

With the object of eliminating a number of intermediate signal boxes the Cheshire Lines Committee, whose supervision extends over 143 miles of railway belonging, in the proportion of two-thirds, to the London & North Eastern, and, of one third, to the London Midland & Scottish Company, have decided upon a somewhat extensive installation of « Transient » track circuits. The first of these was brought into use in January last between Baguley and Northenden on the Glazebrook-Godley Junction line. The whole of the work has been carried out under the supervision of the chief engineer by the Committee's own staff, with the assistance of the Automatic Telephone Manufacturing Co., Limited, of Milton Road, Edge Lane, Liverpool, the contractors for the equipment, under the direction of their signalling engineers. By means of intermediate block working, controlled by the transient track circuits, it has been possible in this case to dispense with the intermediate signal box at Baguley East, and thus to effect a saving of the cost of working the box.


Fig. 1. — Sketch map of the Cheshire Lines Committee's railway and lines worked over, shewing position of Baguley East signal-box, which has been eliminated by the transient track circuit installation.

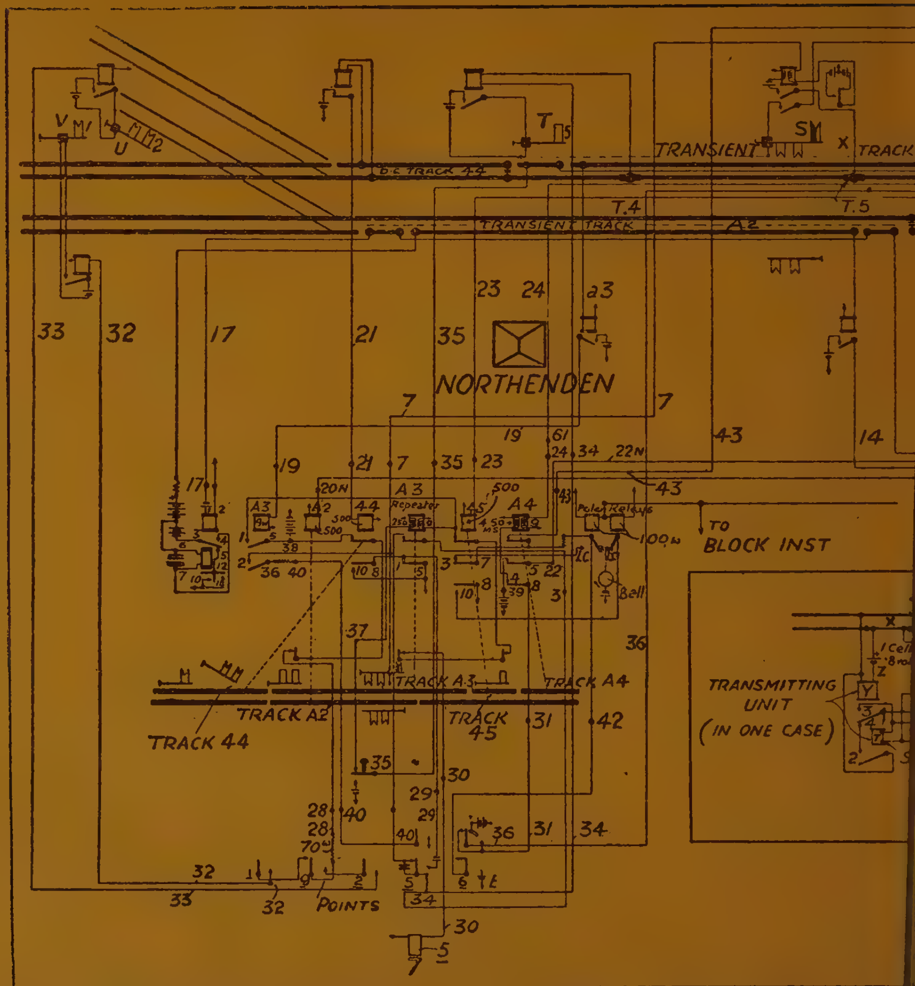
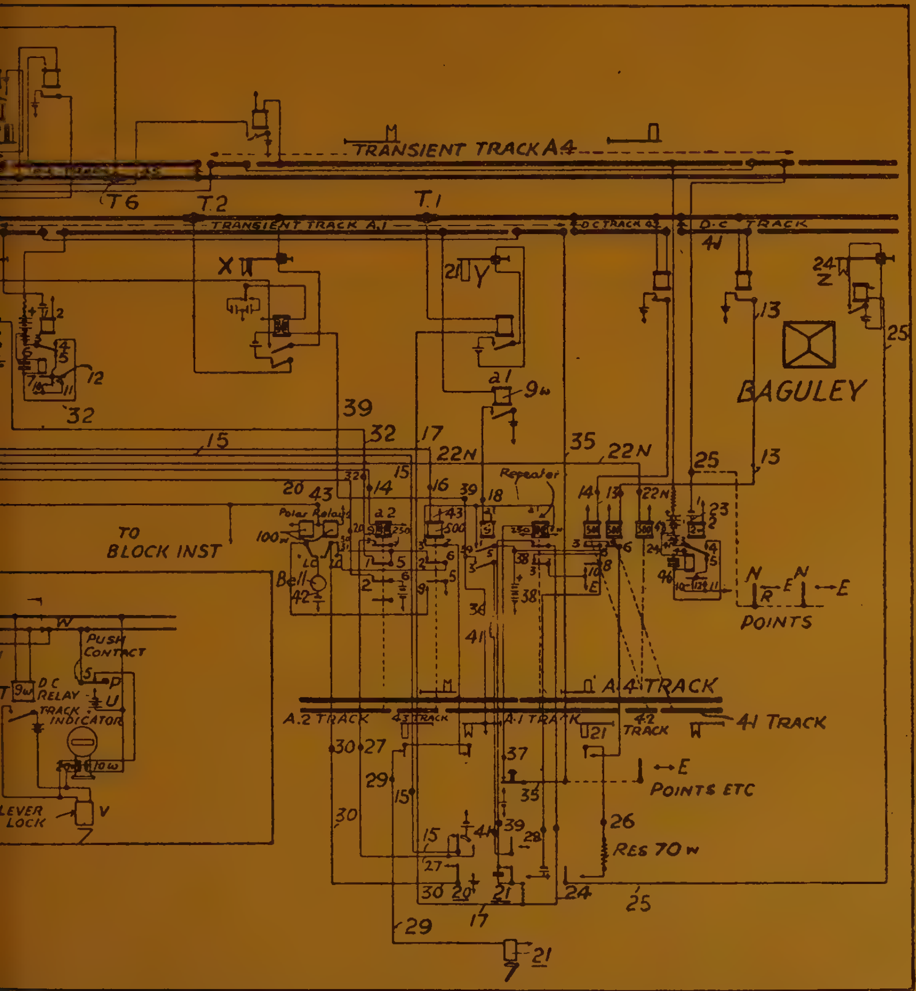



Fig. 2. — Diagram of the transient track circuit
Inset is a diagram illustrating the normal operation of the transient track

## Notable features.

An important feature of this installation, which, it is anticipated, will be the forerunner of several others in different locations, is that both up and down lines are completely track circuited and indicated in the signal boxes at each end of the section. Another feature is that direct current, controlled by a new and improved arrangement, is used instead of alternating current for the transient « sweeping », resulting in a higher degree of safety by improving the « train shunt » and also greatly simplifying the circuits and apparatus generally. In fact, it would appear that the transient track circuit system in this, its latest,




aguley and Northenden, Cheshire Lines Committee.
roduct of the Automatic Telephone Manufacturing Co., Limited, of Liverpool.

form is quite as easy to understand and maintain as the ordinary continuous direct current track circuit. The basic principle of the system, which was originally described in the 9 September, 1922, issue of *Modern Transport*, and has since been considerably improved and simplified, lies in the momentary application of current to the track, which, if unoccupied, will permit the current impulse to pick up a relay.

**Advantages.**

The chief advantage claimed for the system is that current is only applied to the track rails for approximately ten seconds for each train passing over the

track. Taking an average therefore of, say, 120 trains a day, current is flowing for only ten seconds per train, or twenty minutes for the whole twenty-four hours, instead of continuously. The principle is best explained by reference to the typical diagram given as an inset in fig. 2, to which the following is an index :

OPERATION.

| *Signal :* | *Requires :* | *Automatically replaced by :* |
|---|---|---|
| Z. | Lever 24, arm Y « off », tracks 41 and 42 clear . . . . | Tracks 41 and 42. |
| Y. | Lever 21, tracks A1 and 43 clear and signals W and X at « danger ». Cannot again be lowered unless lever 21 is put normal and again reversed. . . . . . . . . | Treadle T1, and tracks A1 and 42. |
| X. | Signal W « off », provided X has not already been passed at « caution » . . . . . . . . . . . . . . . . . | Treadle T2. |
| W. | Lever 20, « line clear » given, tracks A2 and 43 clear, cannot again be lowered unless lever 20 is put to normal and again reversed and « line clear » given. . . . . | Treadle T3. |
| V. | Lever 1, point lever 9 normal, signal T « off », and track 44 clear . . . . . . . . . . . . . . . . . . | Track 44. |
| U. | Lever 2, point lever 9 reversed, signal T « off » and track 44 clear. . . . . . . . . . . . . . . . . . | Track 44. |
| T. | Lever 5, tracks A3 and 45 clear, and signals R and S at « danger ». Cannot again be lowered unless lever 5 is put to normal and again reversed . . . . . . . . . | Treadle T4 and track 44. |
| S. | Signal R « off », provided S has not already been passed at « caution » . . . . . . . . . . . . . . . . . | Treadle T5. |
| R. | Lever 6, « line clear » given, tracks A4 and 45 clear. Cannot again be lowered unless lever 6 is put to normal and again reversed and « line clear » given . . . . . | Treadle T6. |

The track feed battery is normally disconnected at contacts 2. Current is normally flowing from battery Z through relay Y, insulated one rail length X, line wire, insulated one rail length W, contact P and the 10 ohm winding of track indicator to common return rail back to battery Z. The strength of this current is not sufficient, however, to lift the armature of relay Y, or to set the track indicator to the « clear » position when once it has been de-energised. The lever of the signal controlled by the transient track circuit is normally locked by electric lever lock V, and the track indicator stands normally at « clear », being maintained in that position by battery Z.

**Method of working.**

To release lock V on signal lever it is necessary to press and immediately release push contact P, which closes the circuit of battery U through the line wire and relay Y. The normal current from battery Z being thus considerably augmented, the armature of Y picks up and closes the local circuit of the switch relay T through contacts 3. The armature of T picks up and closes contact 2, and the electrolytic valve (which is in parallel with relay T) stores up current. At this stage no current flows from the track feed battery, as contact 4 is broken. Immediately the plunger is releas-

ed, however, relay Y drops its armature and closes contact 4; relay T still holds up its armature owing to its energisation by the stored up current in the electrolytic valve. Current will now be fed to the transient track circuit through contacts 2 and 4 until the electrolytic valve is sufficiently discharged to release the armature of relay T. The track being clear, the direct current relay T will close the local circuit for the lever lock V, as well as restoring the track indicator to the « clear » position. The transient track circuit may be energised for any duration of time according to requirements, usually from three to ten seconds, the time period being adjustable either by the capacity of the electrolytic valve or the weight of armature of relay T.

### Constant indication.

Constant indication is provided for by means of a track indicator having two separate windings, the 10 ohm winding normally maintaining the « clear » indication by current from battery Z. The track indicator falls to the « blocked » position, either when push contact P is depressed (thus breaking the circuit at contact 5) or upon a train passing over the insulated rails X or W, and thereby short-circuiting the 10 w. winding of the track indicator. The track indicator, having once fallen to « blocked », cannot be restored to the « clear » position until the 20 ohm winding is energised, which, of course, can only happen when relay T picks up when the transient track is clear. This form of transient track circuit functions automatically when trains pass in either direction over the track. The short-circuiting of rails X and W causes the apparatus and the track indicator to function in exactly the same manner as when push contact P is operated. A train entering the track at rail W will drop the indicator to « blocked », and when the last pair of wheels have cleared rail X the track circuit will be « swept » behind the train by a transient current impulse which picks up relay 7 and restores the indicator to the « clear » position.

### C. L. C. installation.

The purpose of the new installation on the Cheshire Lines is to provide the possible indication of the state of the section between the two controlling signal cabins, as well as providing complete track circuit control for all signals. Referring to the large diagram (fig. 2), it will be seen that tracks A1, A2, A3 and A4 are all « transient », the remainder of the track circuits 41, 42, 43, 44 and 45 being of the ordinary continuous current type. The transient tracks A1, A2, A3 and A4 each average one mile in length, which is, of course, far from abnormal in the case of a transient track circuit. Nevertheless, owing to low ballast resistance in this locality, it would have been necessary, if continuous track circuits had been employed, to cut up each of these tracks into four sections, thus making sixteen separate track circuits instead of four, with the resulting considerable increase of battery maintenance. All the former mechanically-operated signals throughout the section, including the distant signals at Northenden and Baguley, are electrically operated by battery signal machines, It was considered necessary, in view of the fact that the starting signals are automatically put to danger by the passing of the train, that the distant signals on both main and branch lines at Northenden should be slotted with the down starting signal and that the up distant should be similarly slotted with the up advance starting signal at Baguley. This arrangement, which, of course, entails extra cost, is not by any means essential, but has been adopted solely as an additional safeguard. The arrangement is clearly indicated on the diagram.

### Control of signals.

The starting signals on each road are directly controlled by a transient track circuit up to the next intermediate stop signal, and by an overlap continuous track circuit 440 yards in advance of the stop signal. The intermediate stop signals, in their turn, are controlled by : *a*) A transient track circuit extending up to the clearing point of the section; *b*) an overlap track circuit for the section in rear, and *c*) the indication of « line clear » on the block instrument. The intermediate distant signals are controlled by the intermediate stop signals; but, in addition, a special stick relay circuit is provided. This is the means of preventing the distant arm from being lowered consequent on the lowering of the corresponding stop signal for a train which has previously passed the distant signal in the « on » or « caution » position, and been brought to a stand at the stop signal.

### Audible indication.

Each of the two boxes is provided with a trembler bell, which rings automatically when a train passes the intermediate signals, when « train on line » has not been given, and can only be stopped by the pegging of « train on line » by the signalman in the cabin in advance. In this manner the bell ensures that the indication « on line » is given for every train in accordance with the block telegraph regulations.

### Visual indication.

One of the most interesting features of the new installation is the ingenious type of diagram (shown in figure 5), with which each box has been equipped, and which, we believe, is unique in so far as existing practice is concerned. The diagram itself forms the front of a small cabinet, fixed in line with the signalman's eye, and containing all the relays operating the system which would normally have to be housed in a separate cabinet in the signal box. All the wiring from the outside is brought on to one complete terminal board inside the diagram case, and all local wiring to the various control and indicating relays is also arranged within the case. Views of the cabinet are given in figures 3 and 4.

### The diagram.

The diagram is not of the illuminated type common to most power installations. Models of the signals are superimposed and fitted with working arms, whilst the lettering is stamped on brass plates, which are screwed on to the diagram face, the whole effect being one of neatness and durability. The track circuits are indicated by means of aluminium rollers mounted on specially designed miniature ball bearings; these rollers extend throughout the length of each track circuit, and expose either a white or red segment through slots in the face of the diagram. Each roller is connected by a link to an arm which, in turn, is connected to the armature of its respective track relay mounted immediately above. The track, or repeating, relay from any particular track circuit thus provides its own indication, and by this ingenious system the use of separate indicators, with their extra wiring and separate battery, is avoided. To complete the arrangement all the arm repeaters, which are also fitted with ball bearings, and light indicators have also been brought into the diagram, with the happy result that the whole of the cabin wiring (with, of course, the exception of the connections to lever contacts), the track relays and track indicators and light and arm indicators are not only concentrated into one case, but actually work directly in the diagram, thus dispensing with a row of separate indicators on the cabin shelf.

Fig. 3. — Relay and diagram cabinet, fixed above the lever frame in each signal box.

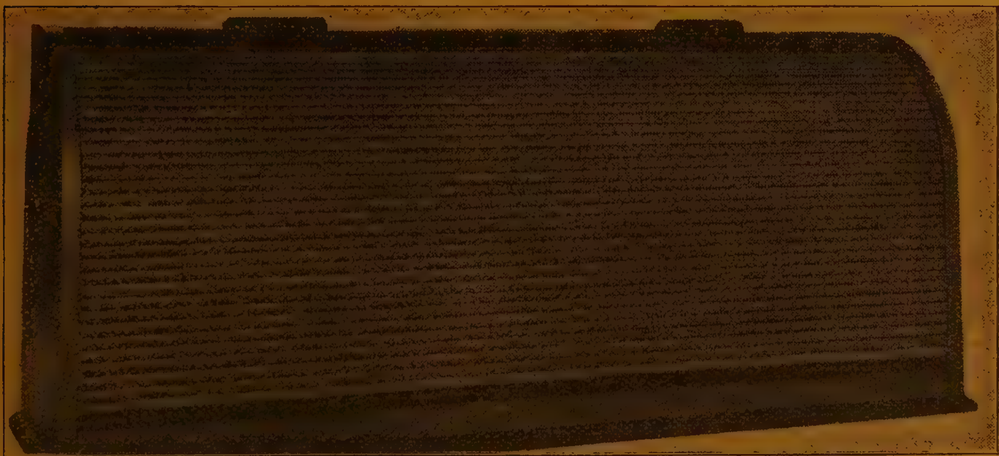


Fig. 4. — Relay and diagram cabinet closed.


Fig. 5. — Track diagram, which forms the front of the diagram and relay cabinet.

### Success of the installation.

We understand that so far the new installation has given every satisfaction and has answered the exacting requirements of this very busy section of line, which is on the through route to Liverpool, followed by the goods traffic of the London & North Eastern and by a large proportion of that of the London Midland & Scottish Company, besides having to accommodate a considerable passenger traffic. Subject to confirmation consequent upon the satisfactory working of the system at the end of three months, the Cheshire Lines Committee have provisionally authorised a further installation, and others will follow at intervals until the railway is equipped with possibly a dozen such installations. By the elimination of a similar number of signal boxes it will be possible to effect considerable savings, which in two or three years will more than cover the capital cost of the installations. One additional technical man alone will be needed to supervise the working and maintenance of the new equipment. The Committee are indeed to be commended on their enterprise in the prosecution of methods capable, not only of yielding substantial economies, but also of facilitating the movement of traffic over busy sections of line.

---

[ 621 .135.4 (.94) & 625 .215 (.94) ]

# Compensation of grades on railway curves in Australia,

By Harold Sutcliffe MORT, B. Sc. B. E.

ASSOCIATE MEMBER OF THE INSTITUTION OF ENGINEERS, AUSTRALIA.

Figs. 1 to 5, pp. 1031 to 1037.

(From the *Transactions of the Institution of Engineers, Australia.*)

### General effects of curve resistance.

Knowledge of the effects of curve resistance is deficient, owing to the lack of exhaustive investigation, the subject being one which cannot be dealt with satisfactorily in the laboratory, and experiments on running track are both difficult and costly.

The chief cause of curve resistance is friction, due to the slipping of the wheels on the rails, while other causes tending to vary it slightly are centrifugal force, acting on the car as a whole, and a force due to the obliquity of traction.

Wellington has shown (1) (p. 282) that the position of a 4 wheeled truck rounding a curve is as shown in figure 1, the flange of the front outer wheel in contact with the rail and the flanges of the other wheels not touching the rail (except when the wheel base is excessively long in relation to the radius of curvature), and the rear axis radial to the curve, this position being unaffected by superelevation. Here the distance $a$ is equal to the versin of the chord $2l$.

The slipping is (1) longitudinal, due to the difference in length of the inner and outer rails, which is equal to $\frac{g}{r} \times$ distance travelled, and (2) lateral slipping, due to the pressure of the rail on the flange of the front axle only.

(1) *Economic theory of railway location*, by A. M. Wellington, 6th. Ed., 1914.

Theoretically both wheels should slip longitudinally, but actually the wheel which first begins to slip will probably continue to do so, as the coefficient of friction when in motion is less than that at starting. The longitudinal slipping is increased by the tendency of the outer wheel to climb on the rail, thereby increasing the diameter of the portion in contact with the rail.

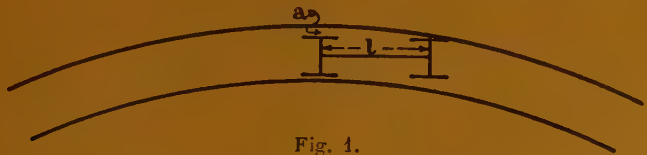


Fig. 1.

A full discussion of the mechanics of curve resistance may be found in Wellington (*op. cit.*) chapter VIII. Among his conclusions are the following :

« Obliquity of traction and the length of the train have very little effect in modifying curve résistance.

« Centrifugal force tends to increase resistance, while superelevation tends to decrease it, but in both cases the effect is very small.

« Rail wear and curve resistance are practically proportional to degree of curvature, where the condition of the track is similar; but as the outer rail is worn away to the shape of the flange, both rail wear and resistance increase.

« With all in order curve resistance may be as low as 1/3 lb. short ton (0.37 lb. per ton), per degree of curve, while with worn rails it may reach double that amount.

« Curve resistance per degree of curve is probably less on sharp than on flat curves, and is greater at low than at high speeds.

« For a given wheel base, the resistance increases slightly with the gauge, and for a given gauge it increases considerably with the wheel base. »

The increase of friction with wear of rails is shown clearly in figure 2, where it will be seen that, when rail and wheel are new, there is only a point contact between them, while when they are worn (shown by dotted lines), there is line contact.

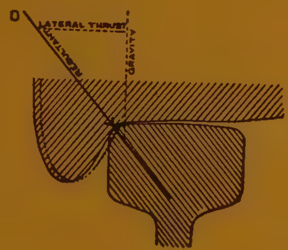


Fig. 2.

The minimum amount of curve resistance may be taken as 0.37 lb. per ton per degree of curvature; this is equivalent to a grade of 0.11 foot per chain, or 1 in 6 000. A one degree curve has a radius of 86.828 chains, and the radii corresponding to other degrees of curvature may be found by dividing this number by the number of degrees; this will be sufficiently accurate for all curves up to 20°.

On most grades the effect of curvature will be averaged by momentum, so compensation may be dispensed with, but on the maximum grade this cannot be permitted, and ample reduction of grade should be provided, especially near stations. The principal reason for this is that on heavy grades the speed is low, especially near the top of the grade, and the momentum consequently small, so that if any extra resistance (*e. g.*, a head

wind or badly worn rails), is met with, the train may stall. If a train, which is just able to move at 12 miles per hour on a ruling grade encounters a 10 chain curve, the extra resistance will amount to 4.86 lb. per ton, equivalent to a rise of 0.143 foot per chain, which would bring the train to rest in about 35.7 chains or about 205° of angle — conditions which might very well be encountered with reverse curves in hilly country. Another reason for full compensation on maximum grades is that a stoppage may be necessary at any point on the line, and if it occur on a curve on which the grade is not compensated the train may not be able to start again. The effect of a stoppage is to add about 0.22 foot per chain to the grade owing to the difference between starting and moving friction.

In compensating for curvature the following general principles may be observed :

With short grades, or under favouring topographical conditions, compensate as liberally as possible.

Where speed may sometimes be very low, and invariably near known stopping places the compensation may be as great as 0.07 % per degree of curvature, but, in general, half this amount is sufficient.

On sections where curves predominate over straights compensation should be ample, but where the curves are few it is less important.

On minor gradients, compensations may be omitted, so long as the virtual profile is kept below the maximum. The effect of the curvature will then be equivalent to a slight undulation of gradient.

It is not necessary to adapt the compensation to the exact length of each curve, but the grade must never rise above the uniform grade lines.

Curves immediately below a known stopping place for all trains need not be compensated.

**Amount of compensation.**

The actual resistance on curves is not a constant quantity which can be found accurately, so that the amount of compensation necessary may vary between fairly wide limits. The object of compensation is to equalise to the best of ability the resistance on curve and straight so that the train is no more likely to stall on one than on the other. It may be advisable to increase the rate on very tortuous lines, while on lines with only a few curves the rate may be diminished. Again, on a long grade an excessive rate of compensation may result in a considerable increase in length in order to reach the summit of the grade.

Wellington (chap. XVIII), recommended 0.05 % per degree of curvature, and this figure was adopted about 1913 for the New South Wales Railways (which up to that time had not made use of compensation, although the question had been raised about 1908), for all curves of 8 chains radius and over, while the allowance per degree on sharper curves was rather less. The experiments on which Wellington's figures were based were carried out in 1878, and since then, owing possibly to improvements in both material and manufacture of rails and tyres, the consensus of opinion has been in favour of a smaller allowance, the majority of railways in Europe and America using 0.035 % or 0.04 % per degree of curvature. In 1922, the New South Wales Railways adopted the following rule :

« Compensation shall be allowed for curves on grades, a curve being considered equivalent to a grade of 1 in 0.5 R where R is the radius in feet. »

This is equivalent to an allowance of 0.035 % per degree of curvature.

The practice in the other States of the Commonwealth and New Zealand (excepting Tasmania, from which the information could not be obtained), is given in table I.

With regard to sharp curves, Wellington says (p. 305) :

« While so obscure a point cannot be considered as established by the existing experimental evidence, all the more trustworthy existing evidence seems to combine with theory to indicate that curve resistance per degree of curve is very much greater on easy curves than on sharp curves; so that when the resistance is 1 lb. per ton for example, on a 1° curve, it may be 6 to 8 lb. per ton on a 10° curve, and not more than 15 to 18 lb. per ton on a 40° to 50° curve. »

This conclusion has been borne out by experiments made subsequently on the New York Elevated Railway and elsewhere.

Later (p. 633) he suggests, as a rough rule, that the rate be reduced by one half for the excess over 10°, or if this is expressed in a formula and Wellington's figure of 0.05 % per degree for the flatter curves adopted :

C = 0.5 + 0.025 (D — 10) where C is expressed in feet per hundred, and D is the degree of curvature.

This formula was adopted by the New South Wales Tramways about 1914 and has been used ever since, the question of sharp curves not having been considered when the formula for railway curves was revised in 1922, and as no new tramways have been built since then, it has not again arisen. To bring the tramway practice into line with that of the railways, Wellington's rough rule should be adhered to, but 0.035 % substituted for 0.05 % per degree of curvature. This would also apply to railways with curves of less than 8 chains radius.

In dealing with trams, or multiple unit electric trains, no loss of power is experienced, due to obliquity of traction on curves, as each truck is driven by its own motor. The effect of this, though small, is to lessen the curve resistance, a further factor in the case of trams being the shorter wheel base.

Another method of expressing the compensation is as follows :

Compensation per chain = 0.07 $\theta$ where $\theta$ is the tangential angle (expressed in degrees), for an arc one chain in length.

Note :

$$\theta = 28.6479 \div R \text{ where } R \text{ is expressed in chains.}$$
$$\theta = 1890.76 \div r \text{ where } r \text{ is expressed in feet.}$$

Where the curve is expressed in degrees

If R = radius in chains

D = curvature in degrees

$$R = \frac{100}{66} \times \frac{180}{\pi} \times \frac{1}{D},$$

in the case of flat curves, where the difference between arc and chord is negligible.

Tangential angle for radius R is $\frac{180}{2R\pi}$

Substituting for R,

$$\frac{180}{2} \times \frac{66D}{180 \times 100} = 0.33D$$

so that the compensation per chain becomes 0.0231D feet, and the compensation per cent 0.35D.

Taking the formula adopted by the New South Wales Railways,

$$1 \text{ in } 0.5\,R = 1 \text{ in } \frac{9\,000}{\pi D} \text{ or } \frac{\pi D}{90}\ \%,$$

giving 0.0349 % per degree of curvature.

In New South Wales, curves of 60 chains radius and over are not compensated, as the extra resistance is negligible compared with the variation due to inequalities in the track, worn rails, head winds, etc.

### Allowance in the field for compensation.

By expressing the compensation as 0.07 $\theta$ foot per chain, a very simple method is obtained of roughly allowing for compensation while carrying out a preliminary traverse. The rule is as follows :

Set the instrument for the angle of depression, or elevation, for the grade required (uncompensated).

Divide the deflection of the horizontal angle, expressed in degrees, by 30.

The result will be the correction, in feet, to give the level of the compensated grade, irrespective of distance.

*Example:* Take the traverse OABCDEF (fig. 3) for a curve on a falling grade of 1 in 110.

Set the theodolite at $\tan^{-1} \frac{1}{110}$, or 0°31′20″ depression.

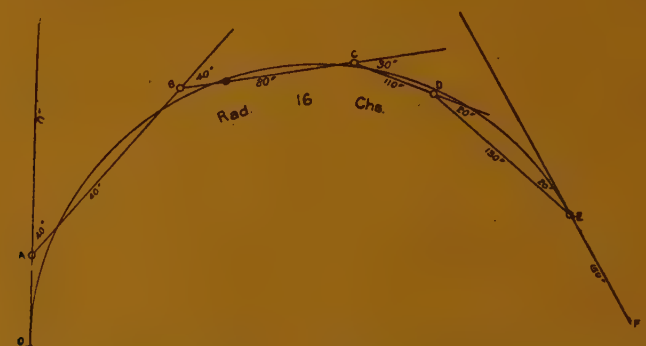



Fig. 3. — Running a grade by angular elevation or depression allowing for compensation.

The deflection angle at A is 40°, so that the correct level of B will be 1.33 feet above the line of sight.

The deflection angle at B is 40°, making a further correction of 1.33 feet at C.

At C the deflection angle is 30°, and the additional correction at D is 1 foot. At D the deflection angle is 20°, and the additional correction at E is 0.66 foot, making a total correction of 5 feet.

The grade may be corrected to the proper level at whatever stations are most convenient.

After plotting the traverse given in the example, it is found that a 16 chain curve fits the location best. The length of this will be about 42 chains and the compensated grade 1 in 139, giving a total fall of 19.95 feet, — the difference being 5.25, as against 5.0 by the field method.

Where the country is heavily timbered or undulating, so that it is not convenient to run a grade with the instrument, the grade can be obtained by levelling along the traverse; the compensation may then be allowed for by using the deflection angles as explained above and the correction made on the ground at short intervals.

For curves less than 8 chains radius, the compensation found by this method will be slightly in excess of what is required.

### Compensation on transitions.

It will be clear from the above that the total compensation depends on the angle turned through, and is independent of both the radius of curvature and the ruling grade. This greatly simplifies the process of compensating where the radius is changing, as on transitions.

The correct rate of compensation per chain, to use on transition, may be found

by dividing 0.7 Φ (1), expressed in degrees, by 20 times the length of the transition, or roughly by dividing Φ by 30 times the length of the transition. *E. g.,* on a 4 chain transition to a 15 chain curve : Φ = 7.8072, compensation per chain = 0.065.

In New South Wales the standard length of transition is 4 chains, which is less than the normal train length, so that there is no objection to spreading the compensation evenly over the transition.

In practice changes of grade are made only at chain pegs and as the radius of curvature at the end of the first chain of the transition is over 60 chains, it is sufficient to apply compensation on the transition for three chains, beginning at the first chain peg after the tangent points and changing to the compensation corresponding to the radius of the circular curve at the last chain before the transition.

*To take an example :* — On a 16 chain curve with a 4 chain transition the chainages are

| | |
|---|---|
| T. P. | 1623.12 |
| Trans | 2023.78 |
| » | 2954.35 |
| T. P. | 3355.01, |

the uncompensated gradient being 1 in 110

The grade of 1 in 110 will be continued to 17 chains; from 17 chains to 20 chains the grade will be 1 in 124; from 20 chains to 30 chains the grade will be 1 in 139; from 30 to 33, 1 in 124; and from 33 chains onward 1 in 110.

This practice has been adopted in the past in the case of several New South Wales lines, but it is doubtful whether it is worth while to change the grade so frequently, when owing to the length of the train being distributed over the circular curve, transition and straight, it would probably serve the purpose equally well to compensate as for the circular curve, from say, the second chain peg before the circular curve to the second chain peg after — an average of three chains on the two transitions.

As, however, experiments have shown that the resistance is considerably greater on the earlier part of the curve, a more satisfactory method of dealing with transitioned curves would be to commence the compensation on the last chain peg before the tangent point at the downhill end of the curve and continue it to the upper transition point. This would provide a slight momentum effect to overcome the greater resistance on the earlier part of the curve.

When the transition is less than 4 chains in length, the rate of compensation is that given in the tables for the circular curve, and extends from the first chain peg past the near tangent point to the last chain peg before the far tangent point.

For the preliminary grading in the field, it is customary to allow the full compensation for the whole length of the curve between tangent points, the object being to allow a little latitude when the line is being finally graded in the office.

In some railways the rate of compensation is varied with the gradient, *e. g.,* in Mexico, where the rate varies from 0.06 % per degree on 1 in 140 to 0.04 % on 1 in 50 but as the extra resistance is independent of the grade, the reason for this is not apparent.

### Effect of stoppages.

If the line is unfenced, the train may have to stop at any place owing to straying cattle. The extra resistance at starting varies, of course with the weather and track conditions, but may be taken as equivalent to a rise of 0.22 foot per chain. This must be borne in mind when grading unfenced lines or station sites, as otherwise it may mean a reduc-

(1) Φ is the angle between the tangents at the ends of the transition. See *The Cubic Parabola, as applied to the easing of circular curves on Railway Lines*; by C. J. Merfield, F.R.S., N. S. W. Vol. xxix., 1895, p. 51.

tion in the maximum load for that portion of the line.

Figure 4 shows at a glance the grade to adopt at station sites for any ruling grade.

### Graphic method.

The rate of compensation and compensated grade may be found graphically from the curves in figure 5. Here the ordinates represent the rise or fall per chain (in feet); in the curves AA, BB the abcissæ represent the radius of curvature, and in the curves CC, DD, EE they are the denominators of the fraction representing the grade.

To use the diagram, take the length of the ordinate on the curve A, B corresponding to the radius of the curve, and with a pair of dividers subtract it from the ordinate corresponding to the ruling grade on the curve C, D, E. The remainder will be the rise or fall per chain on the compensated grade, and the grade corresponding to this will be found on the curve C, D, E.

*For example.* — A curve of 10 chains radius has an ordinate 0.200; subtracting this from 0.66, the ordinate for a ruling grade of 1 in 100, the remainder is 0.46, which is the ordinate on DE corresponding to a grade of 1 in 144.

### Tramways.

In the case of tramways, the compensation allowance in the past has been that given by the formula

$$C = 0.5 + 0.025\ (D - 10),$$

but in the case of sharp curves this is excessive. The reason of this is that the formula used depends on the degree of curvature, *i. e.*, the central angle subtended by a chord of 100 feet, whereas the compensation necessary depends on the angle turned through which is proportional to the angle subtended by an *arc* of 100 feet. For flat curves the difference between the arc and the chord is small, and may be neglected, but when the radius is, say, 3 chains or less, it is appreciable and rapidly increases as the radius diminishes, until with a 66 foot curve the extra compensation due to the difference is 3 inches per chain.

The transition being short — usually about 40 feet — the curve may be compensated from about the middle of one transition to the middle of the other. As the distance between the centres of bogies on most of the 8-wheeled cars is over 20 feet, there would never be more than one bogie at a time on the uncompensated part of the curve.

Double tracks are graded on the centre line, except in very exceptional circumstances, but when grading, the compensation and points of change of grade should be chosen in accordance with the uphill track.

The effect of compensation on grading can be very easily seen by a reference to the Balmoral Tramway. Between the 39 chain peg and the 1 mile 11 chains peg there is a length of 52 chains of which 48 chains is on the ruling grade and 41 chains on curves. The total compensation for curvature on this portion is 28.57 feet, necessitating a lengthening of the line by over 6 chains. As the cost per chain of this portion was, roughly, £600, the extra capital cost was about £3 600 in a little over half a mile of track.

If this amount of compensation was necessary, of course the money was well spent, but if, as is probable, the allowance now adopted for railways can be extended to tramways, the compensation necessary would have been only 20 feet, and two chains, or £1 200, might have been saved.

Another example is the Gilmore-Batlow Railway. Here the total curvature on the line is 5 960° in a length of 21 1/2 miles, an average of 277° per mile, or leaving out the first seven miles, which are fairly level and straight, the remainder has a total curvature of 5 500°, or an average of 374° per mile. As this is equivalent to a uniform curve of 12 1/2 chains radius for 14 1/2 miles, it can be

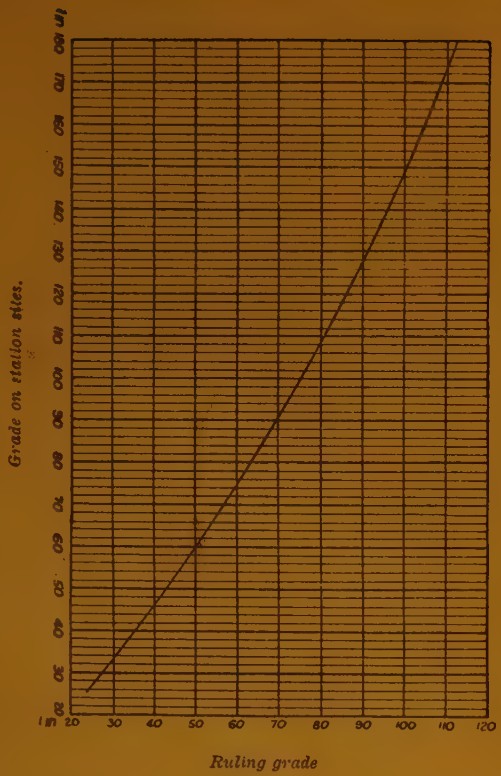



Fig. 4. — Diagram shewing the steepest grade which should be adopted on station sites or other stopping places on fenced lines for various ruling grades.

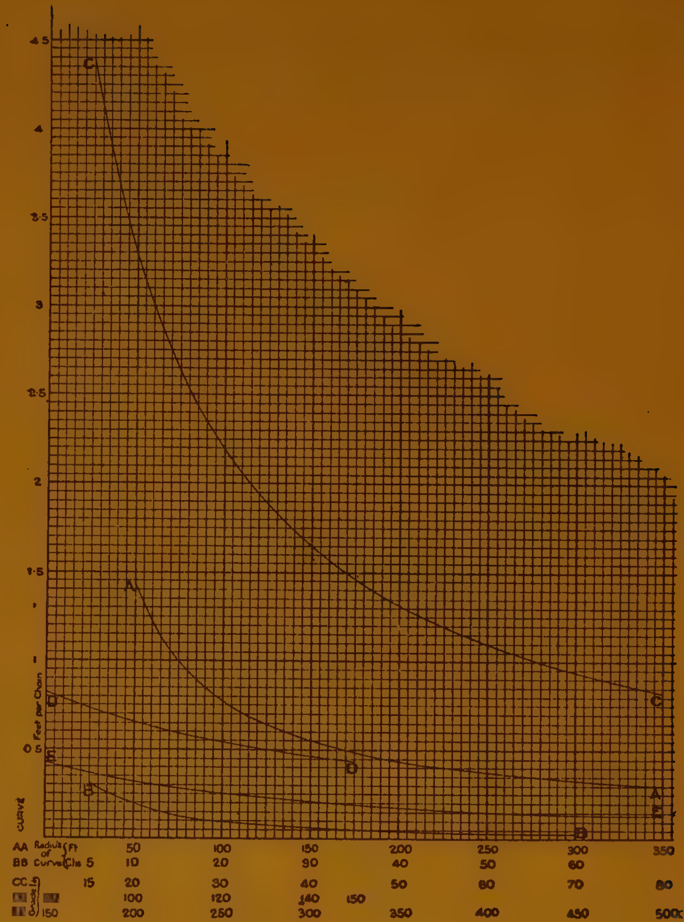



Fig. 5. — Diagram for finding the compensation for curvature on any grade.

seen that it is important from an economical point of view, to keep the amount of compensation down to what is absolutely necessary. On one part of this line in a length of 6 miles 12 chains with a ruling gradient of 1 in 25, and curves as sharp as 5 chains, the total compensation is 137 feet, which means that in order to compensate for curvature the line has to be lengthened about 52 chains, at a cost of approximately £8 000. This compensation was based on the old table, but had the new table been in operation when the line was built, the compensation would have been 96 feet corresponding to a length of 36 chains. Although it does not follow that this length could be actually saved, it is certain that the cost could always be reduced by reducing the compensation allowance, and where it is necessary to develop length in order to reach the summit of a grade, as is the case on many of our lines, the whole cost of the extra length would be saved.

This emphasises the necessity of knowing, as closely as it is possible to discover it, the amount of compensation which will equalise the resistance on curve and straight. This can be investigated very easily in the case of electric tramways, by fitting up a car with a recording watt meter and speed meter, and noting the variation in power or speed over a length of uniform grade. This would be a comparatively inexpensive matter, and the results would probably repay the cost of the investigation.

The configuration of Sydney, especially on the north side of the harbour, is such that almost every tramway built has a considerable length of ruling grade from the water to the highlands, and compensation is always a serious matter.

The question of investigation in the case of railways is rather different. In the first place, the conditions for the flatter curves used in railways have been more thoroughly investigated in other parts of the world, than those for sharp curves, so that although local weather and atmospheric conditions may vary the practice to be adopted for best results in different countries, the need for local investigation is not so pressing. In addition to this the difficulty of obtaining good results is greater. The two principal ways of measuring the power used in overcoming friction in trains, are by the use of a properly equipped dynamometer car between the engine and the train, and the accelerometer method, were the train is allowed to run down an incline by the force of gravity, and the acceleration measured. The latter is a satisfactory method on gentle grades, but on grades such as are usual in New South Wales it is necessary to apply the brakes, making the ratio which track resistance bears to total resistance very small. As what we wish to measure is change of track resistance due to curves, it is easily seen that the variations as shown on an autographic diagram will be too small for accurate measurement. For the dynamometer method of test, a properly equipped car is necessary, and although most large railway systems have these, none has yet been built for the New South Wales Railways.

Still, although it may not be thought worth while to carry out any experiments in this direction at present, it should be borne in mind that if it be decided to do so, there is an ideal testing ground. Between Dubbo and Werris Creek is a length of 9 miles of ruling grade, compensated on the 0.05 % basis for a grade of 1 in 100. On the same line there are several stretches of 3 to 4 miles of 1 in 100 uncompensated.

### Practice in other States.

In addition to the information given in table I, the practice of the other States, in one or two minor matters, may be mentioned.

No other State, except Tasmania, makes any difference in the rate of compensation for sharp and flat curves.

Western Australia and Queensland

compensate all grades; Tasmania all up to 1 in 80; South Australia all up to 1 in 200; New South Wales, Victoria, and New Zealand only ruling grades, while the matter is still under consideration in the case of the Commonwealth.

In Queensland, certain experimental work has been done both by dynamometer and accelerometer methods, but in neither case were the results entirely satisfactory, although the opinion was formed that 0.04 % was, if anything, on the high side.

In Victoria and Tasmania, tests have been made which show the compensation used in those States to be as nearly as possible correct.

In Queensland the question of compensation on roads has received attention from the Main Roads Board, and compensation adopted on all curves of over 30° in length on grades of 5% (1 in 20), which has been adopted as the ruling grade. The amount of compensation varies from 0.04 % on a 1 000 foot curve to 1.28 % on a curve of 80 feet radius. This has been found necessary as the loss in work for a long animal team on a curve is greater than that for any other power.

The case of a motor car was also investigated, but the loss was found to be much less than with a bullock team.

In conclusion the author desires to express his thanks to the Engineers of the various lines of the Commonwealth, the States and New Zealand, and to Mr. Crawford of the Queensland Main Roads Board for information supplied; also to the Railway Commissioners of New South Wales for permission to publish many of the figures quoted in the paper.

## APPENDIX.

Table I gives the gauges, rate of compensation, steepest grade and sharpest curve on the railways of the Commonwealth and New Zealand.

Table I-A gives a comparison between the actual amounts of compensation adopted on the different systems for all curvatures used.

*Note.* — In calculating the tables in this paper, the term « Degree of curvature » has been taken to mean the angle subtended by an *arc* of 100 feet in every case.

TABLE I.

| SERVICE. | Gauge. | Amount of compensation, in feet. | Steepest grade. | Sharpest curve. |
|---|---|---|---|---|
| Commonwealth | 4 ft. 8 1/2 in. | 0.04 per 100 feet per degree of curvature. | 1 in 80 | 20 chains. |
| | 3 ft. 6 in. | | 1 in 51 (1) | 10 — |
| New South Wales: | | | | |
| Existing lines | 4 ft. 8 1/2 in. | 0.05 % per degree of curvature. | 1 in 25 | 5 — |
| New lines | | 0.035 % — — — | | |
| Victoria | 5 ft. 3 in. | 0.035 % — — — | 1 in 30 | 8 — |
| | 3 ft. 6 in. | 0.035 % — — — | ... | 400 feet. |
| South Australia | 5 ft. 3 in. | 3/Rft. per ch. where R is the radius in chains | 1 in 39.6 (2) | 10 chains. |
| | 3 ft. 6 in. | 2/Rft. per ch. | ... | 7 — |
| Western Australia | 3 ft. 6 in. | 0.04 % per degree of curvature. | 1 in 30 | 5 — |
| Queensland | 3 ft. 6 in. | 0.04 % — — | 1 in 25 | 5 — |
| Tasmania | 3 ft. 6 in. | | 1 in 32 | 3 — |
| New Zealand | 3 ft. 6 in. | 0.04 % per degree of curvature. | 1 in 35 | 5 — |

(1) Actual grade is 1 in 60, uncompensated on a 10 chain curve.
(2) Actual grade is 1 in 45, uncompensated.

TABLE I-A.

Comparison between lines of the Commonwealth, the various states and New Zealand.

| RADIUS CHAINS. | South Australia, 5 ft. 3 in. gauge. | New South Wales, existing lines. | Commonwealth, New Zealand, Western Australia, Queensland. | Victoria, New South Wales, new lines. South Australia, 3 ft. 6 in. gauge. |
|---|---|---|---|---|
| | Compensation : Feet per chain. | | | |
| 5 | 0.600 | 0.451 (1) | 0.460 | 0.403 |
| 6 | 0.500 | 0.404 (1) | 0.383 | 0.335 |
| 7 | 0 429 | 0.370 (1) | 0.328 | 0.287 |
| 8 | 0 375 | 0.344 (1) | 0.287 | 0.251 |
| 9 | 0.333 | 0.319 | 0.255 | 0.223 |
| 10 | 0.300 | 0.287 | 0.229 | 0.200 |
| 11 | 0.273 | 0.261 | 0.208 | 0.182 |
| 12 | 0.250 | 0.239 | 0.191 | 0.167 |
| 13 | 0.231 | 0.220 | 0.176 | 0.154 |
| 14 | 0.214 | 0.205 | 0.164 | 0.143 |
| 15 | 0.200 | 0.191 | 0.153 | 0.134 |
| 16 | 0.187 | 0.179 | 0.143 | 0.125 |
| 18 | 0.167 | 0.159 | 0.127 | 0.111 |
| 20 | 0.150 | 0.143 | 0.115 | 0.100 |
| 22 | 0.136 | 0.130 | 0.104 | 0.091 |
| 24 | 0.125 | 0.119 | 0.095 | 0.084 |
| 25 | 0.120 | 0.115 | 0.092 | 0.080 |
| 26 | 0.115 | 0.110 | 0.088 | 0.077 |
| 28 | 0.107 | 0.102 | 0.082 | 0 072 |
| 30 | 0.100 | 0.095 | 0.076 | 0.067 |
| 35 | 0.086 | 0.082 | 0.065 | 0.057 |
| 40 | 0.075 | 0.072 | 0.057 | 0.050 |
| 45 | 0.067 | 0.064 | 0.051 | 0.045 |
| 50 | 0.060 | 0.057 | 0.046 | 0.040 |
| 55 | 0.054 | 0.052 | 0.042 | 0 036 |
| 60 | 0.050 | 0.048 | 0.038 | 0.033 |

(1) Calculated from formula $C = [0.5 + 0.025 (D-10)] \times 0.66$.

# MISCELLANEOUS INFORMATION

[ 621 .335 (.44) ]

## 1. — Express electric locomotive for the Midi Railway Company of France.

Figs. 1 to 3, pp. 1041 to 1045.

(From *Engineering*.)

In view of the large electrification problems in hand, the French railways are testing out various types of electric locomotives, in order to develop permanent standards suitable to their traffic. The express electric locomotive illustrated in figures 1 to 3, is an ingenious, and, it is reported, successful attempt to deal with some of the problems involved.


Fig. 1. — General view with side panels removed.

Two of these machines have been built at the Tarbes works of the Constructions Electriques de France, for the Midi Railway Company of France, and have been running satisfactorily for some time. A speed of 75 miles per hour has been maintained with ease in ordinary working, while 93 miles per hour has been recorded in trial runs on which no abnormal vibration or oscillation was apparent.

As will be seen from figure 1, the design embodies three pairs of driving wheels. The normal horsepower transmitted is 789 per

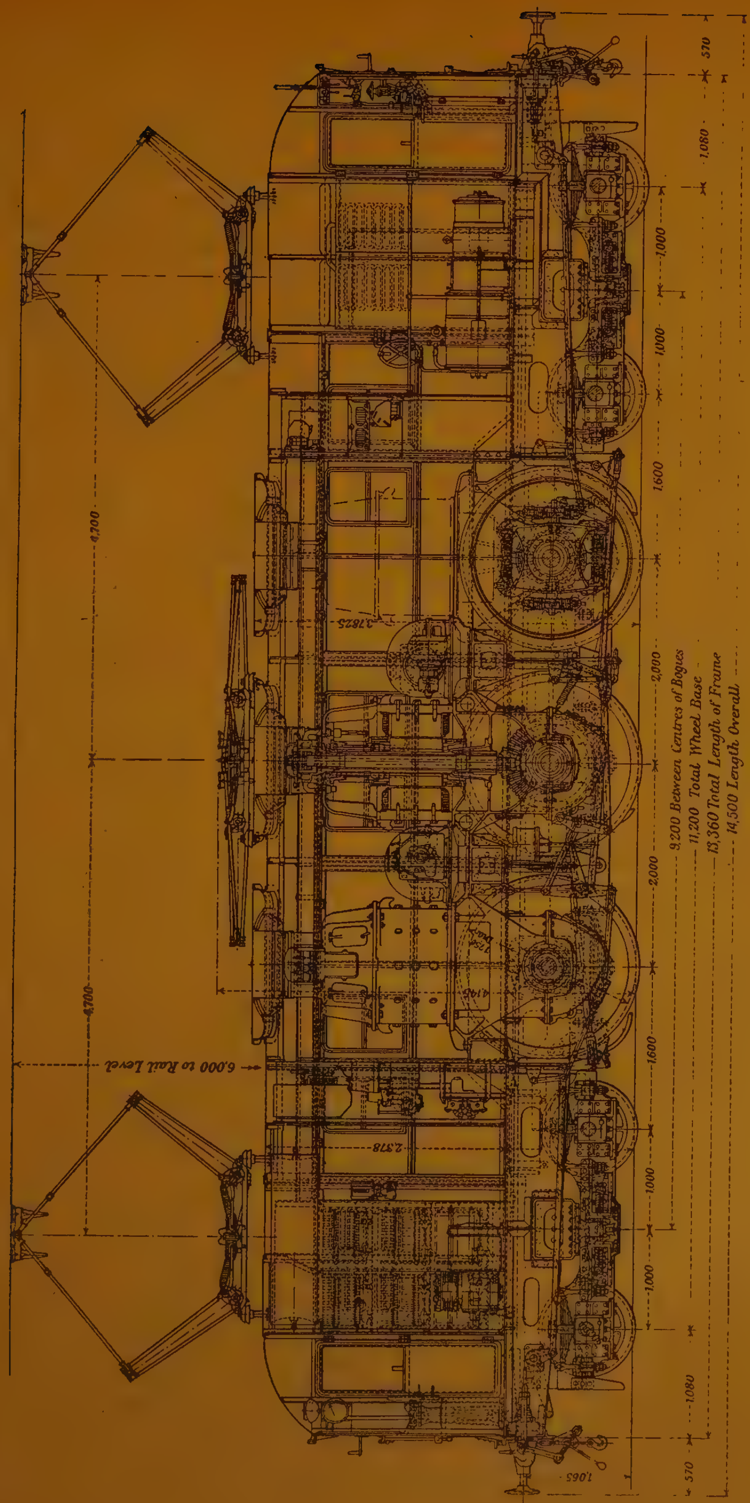
axle. This can be increased, when necessary, to 986 H. P. per axle. To provide a torque of this magnitude on one axle would have involved a very large motor with, in consequence, difficulties in arranging accommodation for the driving gear between the main frames. Reference to figure 3 indicates very clearly the arrangement finally adopted, namely, two vertical-spindle motors for each driving axle, or six in all. The principal particulars of the locomotives are as follows :

| | |
|---|---|
| Diameter of driving wheels | 1.750 m. (5 ft. 9 in.). |
| Diameter of bogie wheels | 0.900 m. (2 ft. 11 1/2 in.). |
| Distance between centres of bogies | 9.200 m. (30 ft. 2 in.). |
| Distance between bogie wheel centres | 2.000 m. (6 ft. 6 11/16 in.). |
| Total wheel base | 11.200 m. (36 ft. 9 in.). |
| Distance between driving wheel centres | 2.000 m. (6 ft. 6 11/16 in.). |
| Distance between the bogie wheel centre and the nearest driving wheel centre | 1.600 m. (5 ft. 3 in.). |
| Total length of body | 13.360 m. (43 ft. 10 in.). |
| Width inside body | 3.080 m. (10 ft. 1 in.). |
| Length over buffers | 14.500 m. (47 ft. 7 in.). |
| Height from rail to top of roof | 3.780 m. (12 ft. 5 in.). |
| Weight on each driving axle | 18 metric tons. |
| Weight on each bogie axle | 12 — |
| Weight available for adhesion | 54 — |
| Total weight | 102 — |
| Drawbar pull | 12.5 — |

The driving connection between the motors and driving wheels is by means of a quill. In this drive, the axle is allowed a certain amount of movement relatively to the quill, the only stress transmitted being that of the torque. The quill, which is 320 mm. (12 5/8 inches) in external diameter in the journals, and 270 mm. (10 1/2 inches) in internal diameter, has fixed to it at each end a disc provided with four projecting arms. Between this disc and the driving wheel, is a loose ring carrying four lugs. Two of these lugs are connected with the quill disc, and two with the driving wheel. This connection consists, in each case, of a pair of helical springs which are shown in figure 2. These abut against the short arms of the quill disc at two opposite sides of the ring diameter, and against bosses on the driving wheel at the other two sides. Ball and socket joints are provided at all eight points of contact.

The power is transmitted through the springs. The whole arrangement is very flexible and permits movement of the axle in all directions. The quill, of course, runs without endplay in its bearings, which are of considerable width. Referring again to figure 3, in the centre of the quill between the two bearings there will be seen to be keyed a casting which carries two bevel wheel rims securely fixed to it, back to back. These are of special hard steel, not heat treated, and have each 60 teeth. They each mesh with a 22-tooth pinion, of heat-treated chrome-nickel steel, on the vertical motor shafts. As the bevel pinions gear one on each side of a single wheel having two faces, they have to rotate in opposite directions. This arrangement obviates all lateral thrust on the quill bearings. The motors, as stated above, are vertical, and each pair is housed in a common stator casing, with main and reverse winding. They do not, in themselves, call for special comment, except that, as the vertical arrangement adopted gives plenty of room, they are amply proportioned and have corresponding high efficiency and good insulation.

The fact of the armatures being well above the axles, and rotating in opposite directions, makes for steadiness. The centre of gravity is, as a matter of fact, about 6 ft. 2 in. above the rail level, which compares favourably



9,200 Between Centres of Bogies
11,200 Total Wheel Base
13,360 Total Length of Frame
14,500 Length Overall
6,000 to Rail Level
4,700
4,700
570
1,080
1,000
1,000
1,600
2,000
2,000
1,600
1,000
1,000
1,080
570
1,065
2,378
2,7825


Fig. 2.

with that of 4-4-2 type engines. The period of oscillation is lengthened by this high centre of gravity, and the opposite rotation conduces to better balancing.

It will further be realised from figure 3, that the bevel gearing is completely enclosed. This makes forced lubrication possible. The motor shaft has bearings at the top and bottom, and between these extends a sleeve, thus providing an annular space round the shaft. There is an adjustable thrust bearing with a double ball race at the top. Oil is fed into the ball race casing, whence the upper bearing is lubricated. Part of the supply passes down a hole drilled in the centre of the shaft and into the annular space surrounding it. Hence it passes through the lower bearing into the gear box, in which a constant level is maintained, so that the gear runs in oil. The quill bearings have ordinary lubricating grooves. Labyrinth packing is provided, which effectually prevents the escape of oil at any point.

The ventilation of the motors may also be followed in the same illustration. The shaft, is cased in, as explained above, for lubrication purposes, but the main casing lies outside this oil screen, and into the space between them air is delivered by fans. This passes upwards, through both armatures and fields, and finally escapes through storm-proof removable cowls on the roof of the lovomotive. Overhead, at each side of the engine, the main cables are arranged with the leads to the commutators.

The main frame of the engine is constructed of plates 30 mm. (1 1/4 inches) thick, and is continuous from one buffer beam to the other. It is fitted with outside hornblocks of standard pattern, which carry the axle-boxes of the three driving axles. The journals are 160 mm. by 260 mm. (6 1/4 inches in diam. by 10 1/4 inches long) and the bearing brasses are fitted with the normal wedge adjustment and ordinary lubrication. The axles are 190 mm. (7 1/2 inches) in diameter in the body, so that there is 40 mm. (1 1/2 inches) clearance each side between them and the inside of the quill shaft. This is ample allowance for any possible relative displacement. The driving wheels are of the disc type 1 750 mm. (5 ft. 9 in.) in diameter on the tread. They are keyed to the axles in the ordinary manner, and connected with the quill shaft by the flexible coupling already described.

In addition to the buffer beams and some stiffeners, the frames are connected transversely by six cross bearers. Four of these carry the six main motors and some of the auxiliaries while the other two are for the four-wheel bogies at each end of the engine. The bogies are similar in design to those of the 4-6-2 type of engines on the Midi Railway. They have inside axle-boxes and direct suspension by laminated springs. The spherical centre is allowed some vertical movement in the bolster on which the weight is carried by two cup-shaped bearings. The lateral play of 55 mm. (2 1/8 inches), which is allowed on each side of the centre line, is damped by two laminated springs, each of which is loaded to 7.5 t. The engine is arranged with three-point suspension, the load being taken by the two bogie pivots and by the central group of six springs fitted under the driving boxes and coupled by equalising gear.

The auxiliary equipment is well thought out. As already stated, forced lubrication is employed on all the main parts except the axle-boxes. It is provided by two independent motor-driven pumps, one for normal working and the other as a stand-by. The action is automatic, and there is an adjustable valve for controlling the circulating pressure, which is normally about 8.5 lb. per square inch. The temperature of the oil in circulation is carefully watched as affording an indication of correct working of the main working parts. The oil passes through a filter tank during circulation. A hand pump is provided for oil circulation should the engine have to be towed at any time.

The main motor ventilation is effected by two motor-driven fans. These and the oil pumps are shown in figure 2 between the main motors, and are also clearly visible in figure 1.

A motor-driven Westinghouse air compressor, of a capacity of 64 cubic feet of free air per minute at about 100 lb. pressure per square inch, is provided for braking purposes. It is

controlled by an automatic switch which comes into action between 70 lb. and 100 lb. per square inch. The air compressor has automatic lubrication, and is air-cooled. There are two brake cylinders, of standard type, for the driving wheels, and separate gear for the bogies. The position of the blocks is shown in figure 1. With the exception of the fans, which are driven by motors in series, taking direct current at 750 volts, the whole of the auxiliaries are supplied with current from a 15-kw. motor-generator set. This is shown on the right of figure 2 above one of the bogie bolsters. The motor of this set takes the main line supply at 1 500 volts direct current, and drives a generator producing 120-volt current. The set, as a whole, is designed to be self-regulating as far as possible, in order to produce a steady voltage of 120 in the auxiliary circuits, even should the main current fluctuate. The set is started up automatically whenever the locomotive is started. The lighting circuit, as well as that of the auxiliaries, employs 120 volts direct current.

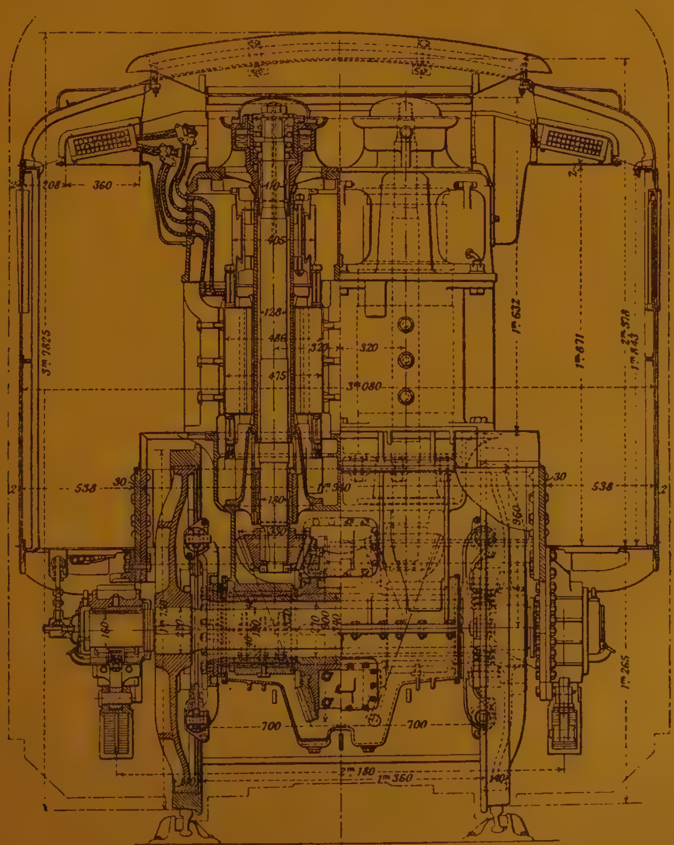


Fig. 3.

The locomotive is subdivided into several compartments. At each end there is a driver's compartment commanding an unrestricted view of the line.

The switch panels are in a separate compartment. The system adopted is of the English Electric Company's « cam switch » type, actuated by a servo-motor under the control of the operator but locked automatically when any change has been made. The four circuit breakers, grouped in pairs in parallel, are also of the English Electric Company's pattern. The auxiliary controls are supplied with 120-volt current from the motor-generator set, the latter being started automatically by a contactor switch.

The starting resistances, of which there are three, each enclosed in a separate compartment, have cast-iron grids with mica insulation. In order to simplify the connections, only two arrangements of grouping have been provided, *i. e.*, six motors in series, and two sets of three in parallel. This will be modified in future engines, and a third alternative provided to ensure smoother starting. It may be noted here that it is also intended to abandon the direct-driven fans and to run them by the auxiliary current at 120 volts.

The current is collected by two pantographs from a single line at 1 500 volts. The contact strip is of copper, 4 mm. (0.157 inch) thick, and is renewed when worn to 2 mm. (0.078 inch). This, it is stated, occurs after running from 7 500 to 9 300 miles. A third pantograph, situated in the middle of the locomotive, is provided as a stand-by.

The principal dimensions have already been given in the table, and are also shown in figures 2 and 3. The normal total horse-power is 2 367. This can be increased to 2 958 if necessary. The weight on each driving axle is 18 metric tons, which gives an available weight for adhesion of 54 metric tons. The total weight of 102 metric tons is made up by a bogie load of 48 tons — that is, 12 tons per axle.

As stated above, two locomotives have been well tested on service runs, and a further eight are being built for the Bordeaux-Irun line. Apparently, however, the type is not yet powerful enough, and future designs will have eight vertical motors on four driving axles, giving a draw-bar pull of 16.6 metric tons and a fixed wheel base of 6 m. (19 ft. 8 1/16 in.), as compared with 12.5 metric tons and 4 m. (13 ft. 1 3/8 in.) the corresponding figures for the locomotives described above.

---

[ **621** .335 (.47) & **621**. 43 (.47) ]

## 2. — Geared Diesel locomotive for the Russian State Railways.

Figs. 4 to 11, pp. 1047 to 1053.

(*The Engineer.*)

The chief problem to be solved in the application of the Diesel engine to locomotives lies in the means of transmitting the power of the engine to the driving axles. The characteristics of the internal combustion engine are such that a direct drive like that of a steam locomotive is practically out of the question. It is true that a Diesel locomotive with direct drive has been built, such an engine having been tried in 1912 on the German State Railways, but the tractive effort amounted to less than 3 tons, and the starting of the machine with compressed air was extremely uneconomical. Some sort of transmission gear obviously had to be interposed, and various designers have worked along three main lines, namely, either the use of an electric drive or the employment of mechanical gearing, or the provision of some kind of fluid-operated speed-changing device. There is, of course, also the possibility of combining the internal combustion engine with a steam engine on the Still principle, but that is really a composite machine.

The only kind of transmission which, so far, has come into practical use is the electrical one, which dates from 1917, and several engines, of powers up to 1 000 H. P., with

electrical transmission are now in operation in the United States. The most powerful Diesel locomotive with electrical transmission is that designed by Professor Lomonossoff for the Russian State Railways, which has been doing ordinary goods train service on the lines around Moscow for more than a year. This locomotive develops 1 200 H. P. It weighs 120 tons in running order and exerts a draw-bar pull of 15 tons. We published a full illustrated description of this machine in our issue of 14 November 1924, and gave the results of its road tests on 27 February last. Satisfactory as this locomotive has proved itself to be, the limitations of electric transmission were realised by no one more clearly than by Professor Lomonossoff himself. The full power of the engine can only be used between road speeds of about 10.6 and 24 miles per hour. At lower speeds, in spite of the weight of the machine, the wheels slip, while at higher speeds the electrical machinery becomes overheated. In summer time it is only possible to utilise the maximum draw-bar pull of 15 tons for 100 minutes. This corresponds to a distance of less than 17 miles at a speed of 10 miles per hour. In European Russia there are no gradients longer than 17 miles, but in the Caucasus there are gradients over 40 miles long, and on these it is necessary to limit the tractive effort to 9 tons only, or very much less than the engine could exert.

The locomotive to which we have referred was built by Professor Lomonossoff in collaboration with the Hohenzollern Locomotive Works at Düsseldorf, and under the same auspices designs were prepared for two other Diesel locomotives, one having a mechanical gear drive and the other having hydraulic transmission. Thus it was hoped that a thorough comparison could be made between the three systems. The locomotive with hydraulic transmission has, however, not been built, because the hydraulic apparatus required to transmit 1 200 H. P. was found to exceed the permissible limits of weight and size. The designs of the geared locomotive proving satisfactory, its construction was proceeded with in the Hohenzollern Company' works at Düsseldorf.

The general appearance of the Lomonossoff-Hohenzollern geared Diesel locomotive is shown in figure 10, which is a reproduction of a photograph of the engine taken on the locomotive testing machine at the Hohenzollern Works. Figure 11 and figure 4 herewith

Fig. 4.

show the locomotive in an advanced stage of erection and enables the main elements to be distinguished. These views, taken in conjunction with the general arrangement drawings (fig. 5) indicate very clearly the general lines of construction. The locomotive runs on ten

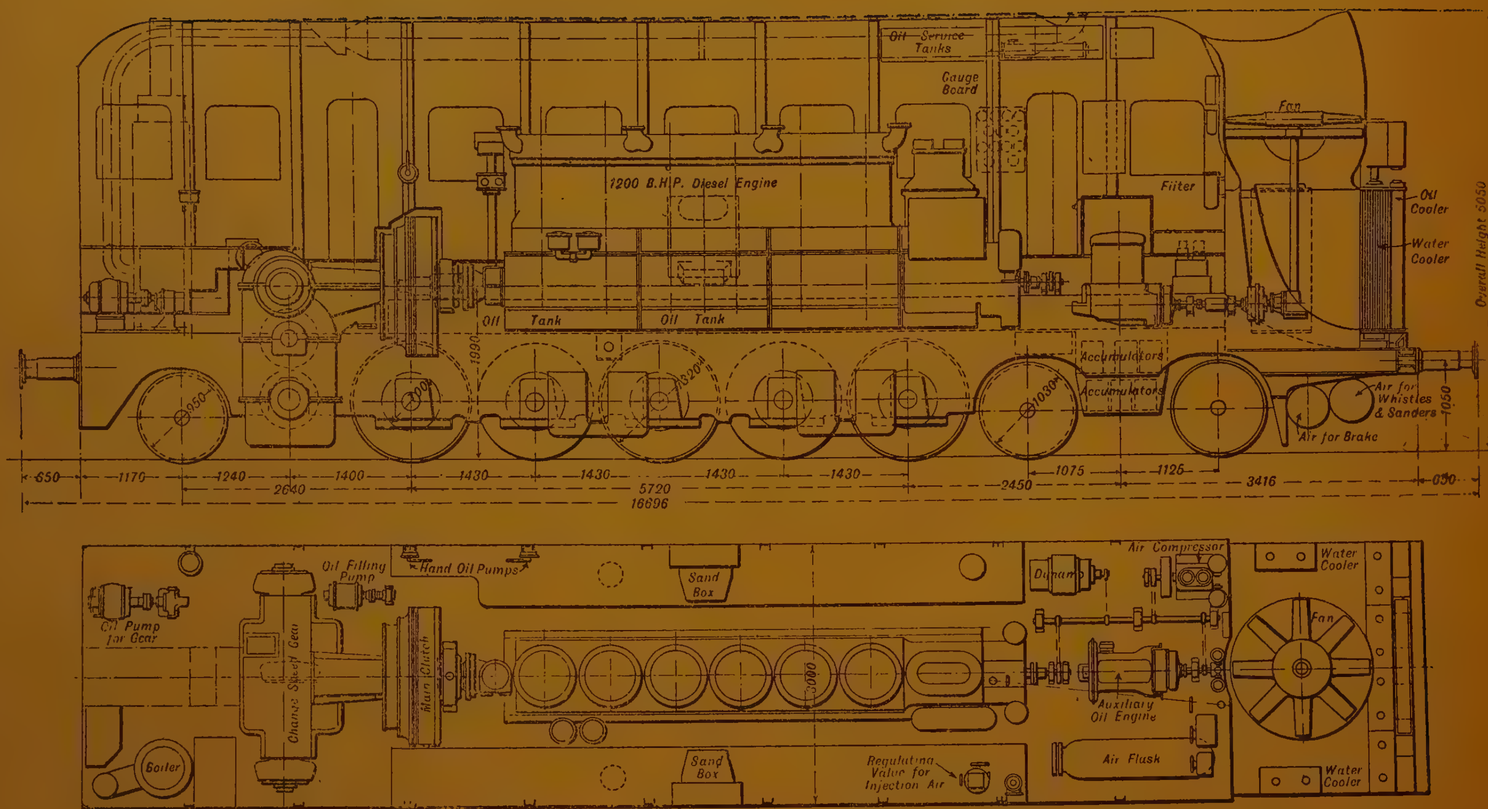



Fig. 5. — Geared Diesel locomotive. — General arrangement.

coupled driving wheels with a bogie in front and a trailing axle behind. The Diesel engine, placed fore and aft in the centre of the frame, drives a jack shaft in the rear by means of a clutch and gearing, and coupling rods connect the jack shaft to the five driving axles. The engine is of the four-cycle type standardised for sub-marines. It has six cylinders, 450 mm. (17 11/16 inches) diameter by 420 mm. (16 1/2 inches) stroke, and develops a maximum of 1 200 brake horse-power at a speed of 450 revolutions per minute. Injection air is supplied by a compressor which forms a continuation of the engine at its forward end. Immediately in front of the main Diesel engine is a small auxiliary motor, also of the Diesel type. This motor drives the cooling fan for drawing air through the water and oil coolers, and also serves as an alternative source of power for the dynamo and the starting air compressor. The two latter machines are to be seen in figure 5 in the plan view of the locomotive. They are chain driven either from the main engine or the auxiliary engine through an intermediate countershaft. Opposite them on the other side of the locomotive is the air storage reservoir.

In the very front of the locomotive is the oil cooler, shown clearly in figures 4 and 10, and immediately behind it is the water cooler. The oil cooler is of the flattened tube type, whereas gilled tubes are used for the water cooler. Air is drawn through them by the fan in the uptake, already referred to. This fan is shown in figures 4 and 5. There are in addition two other water coolers, one on each side of the uptake, which can be seen in the plan drawing and are discernible in figure 4. These can be put out of action when the weather is excessively cold. In figure 10 the air reservoirs for the compressed air brake and for operating the whistle and sanders respectively can be seen lying transversely under the uptake in front of the wheel guards. Between the bogie wheels a convenient space is found for the battery of accumulators, which can be readily withdrawn or inspected from the side. The sand boxes are indicated on each side midway of the driving axles in the plan view. Between the gear-box and the clutch is the motor-driven oil pump for filling the oil tanks. The two rear corners are occupied one by a motor-driven oil pump for lubricating the main gearing and the other by a boiler heated by the exhaust gases. Fuel storage tanks run along each side of the locomotive from the front of the main engine to the back of the clutch, and from them the oil is pumped into the fuel service tanks overhead near the front of the locomotive.

It is, however, the transmission gear which will undoubtedly arouse most strongly the interest of engineers. Motor cars have long since settled down to a friction clutch combined with a three or four-speed gear-box, as a means of connecting the engine to the driving axle. By analogy one might assume that some similar arrangement would be the best for a locomotive, and quite possibly it will prove to be so; but the difficulties of design are vastly greater than those which motor car designers have to face. Not only has a relatively enormous amount of power to be transmitted, but the weight of a locomotive and train is so great that a slow and smooth acceleration is indispensable. Hence the clutching arrangement must have considerable and sustained slipping power to enable the load to be gradually picked up when the locomotive is started or when the gear ratio is changed. The clutch selected for the Lomonossoff geared locomotive was of the magnetic type developed by the Magnet-Werk Company, of Eisenach, Germany. This company have made a speciality of magnetic clutches, which they have supplied in units capable of transmitting up to 20 000 H. P. In the locomotive there are altogether four of these clutches, one being the main clutch between the engine and the gear-box and the other three serving to connect and disconnect the respective gears.

Figure 6 shows a section through the main clutch. Keyed on the end of the engine shaft is a steel disc A which forms the magnet. It is excited by a single coil B let into a circumferential groove in its face, the ends of the coil being brought out to a pair of slip rings on the back of the disc as shown. Bolted to the disc is the heavy fly-wheel rim C,

and to this again is bolted the friction plate D. The fly-wheel rim does not make continuous contact with either the magnet or the friction plate, numerous radial passages being left between them for cooling purposes. Running freely on the outer end of the engine shaft

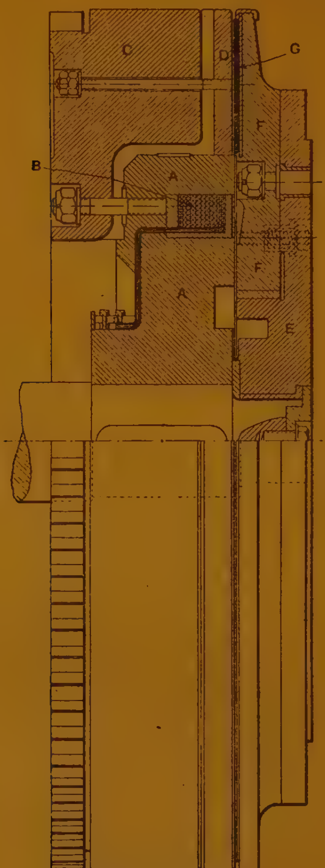



Fig. 6. — Main clutch.

is a disc E through which the gearing is driven. This disc carries an armature plate F, to which is fixed an annulus of friction material G. Exciting current flowing in the coil B causes the disc A to become magnetised and to attract strongly the ring F. The ring moves inwards, against the action of the spring bolts shown, under the magnetic attraction and brings the friction material into contact with the friction plate D, sufficient pressure between the two being obtainable to transmit the power of the engine. By regulating the exciting current the clutch may be allowed to slip to any extent required, and it thus serves as a useful link between the engine and its work, taking up the load gently and avoiding all shock when the gears are changed.

The design of the three magnetic clutches employed in connection with gear changing is shown in figure 7. As before, a steel disc A is keyed to the driving shaft and is rendered magnetic by an exciting coil B. When the coil is excited it attracts the disc C, which, in moving towards the magnet compresses the interleaved friction discs D, half of which are keyed to the external casing E and the other half to A. Thus power can be transmitted from the shaft to the sleeve F by means of the friction of the discs. These clutches are not designed for long-continued slipping, but slip just enough to let their respective drives be taken up without jerks or shocks.

An external view of the gear-box is shown in figure 9, while figure 8 illustrates a vertical section. The gear-box gives three speed ratios, 6.6 to 1, 4 to 1, and 2 to 1 respectively. The gears are always in mesh, the required drives being obtained by the respective clutches. The power from the horizontal driving shaft enters the gear-box and is transmitted to the uppermost shaft C by means of the bevel gear M. It may be mentioned that in 1921, when the plans for this locomotive were under consideration, no gear makers could be got to supply bevel gears to meet the conditions. Eventually in 1923, however, Messrs. Alfred Krupp, of Essen, undertook to supply the gear and to give a satisfactory guarantee as to its performance, and that firm was therefore entrusted with the whole of the gear-box for the locomotive. The bevel gear adopted has a maximum diameter of 500 mm. (1 ft. 7 11/16 in.) and yet is capable of transmitting 1 200 H. P. at 450 revolutions per minute. It is constructed of special heat-treated steel. The slowest speed of all is

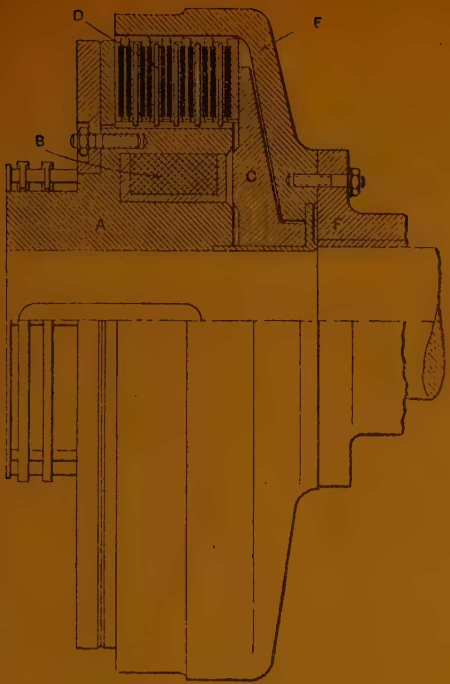



Fig. 7. — Gear change clutch.

Fig. 9. — Gear-box.

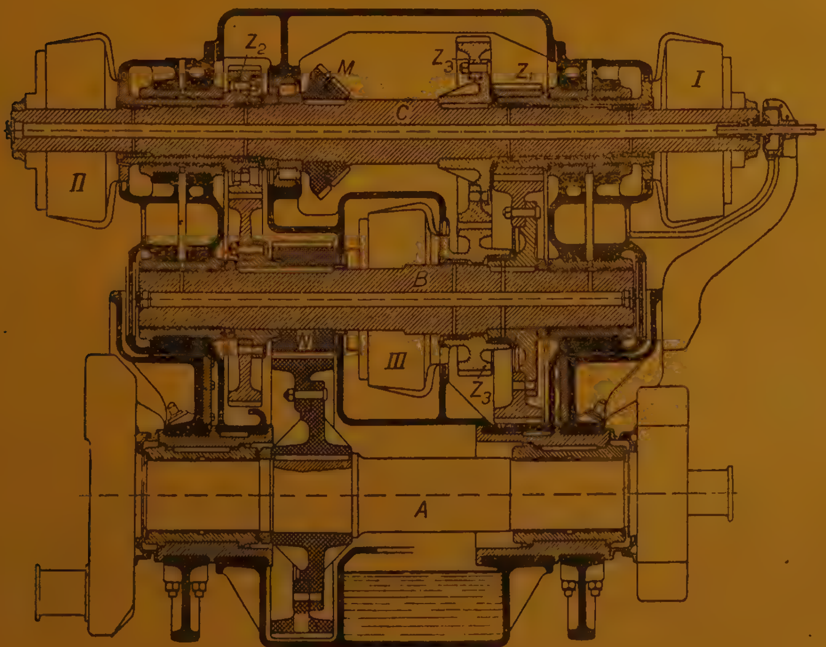



Fig. 8. — Section through gear-box.

Fig. 10. — Locomotive on the test-bed.

Fig. 11. — Locomotive during erection.

obtained by exciting the right-hand clutch I, the other clutches being free. This locks the wheel $Z_1$ to the upper shaft C so that the second shaft B is driven and transmits its power to the jack shaft A at the bottom by means of the fixed gear N. For the intermediate speed the clutch II is the only one excited. This locks the gear $Z_2$ to the second shaft and the continuation of the drive is as before. For the highest speed clutch III on the second shaft is excited. This causes the wheel $Z_3$ keyed to the upper shaft to drive the second shaft, which drives shaft A through the gearing N as before. It should be memtioned that reversing is effected by reversing the direction of rotation of the Diesel engine, which is done by bringing a new set of cams into action in the usual way. The gear in the gear-box therefore takes no part in the process of reversal, but is merely driven in the opposite direction.

The locomotive started on its road tests from Berlin on 26 May, under the supervision of prominent engineers of the German State Railways. It performed all its duties satisfactorily, including the haulage of a train weighing 1 330 tons, exclusive of engine, up a gradient of 1 in 100 about 11 miles long at a speed of 14 km. (8.7 miles) per hour. Lighter loads were hauled at correspondingly higher speeds. The clutches worked satisfactorily. The official figures of the tests are not yet available, but it is said that the locomotive showed a thermal efficiency of 27 to 29 %, or considerably higher than that attained by the Diesel-electric locomotive. Special trials were carried out at the request of the German State Railways, which, as a result of the performance of this engine, have ordered a Diesel geared-locomotive from the Hohenzollern Works for its own system. This engine will be of the 2-10-2 type, with a new design of high-speed Diesel motor and the weight will be about 130 tons.

---

[ 385. (06.2 ]

## 3. — Association of Electrical Engineers graduates of the Montefiore Electro Technical Institute, rue Saint-Gilles, 31, Liége.

---

## The « Eric Gerard » Prize.

Arrangements have been made to found a prize with this title which will be awarded every three years, the first award to be early in 1929 to the author, of Belgian or other nationality, of the best paper on an electrical subject, or on the application of electricity to industrial processes, published in French, in the *Bulletin scientifique de l'Association des Ingénieurs sortis de l'Institut Electrotechnique Montefiore*, which has been read previously before a meeting of Engineers of this Association.

The funds required for the prize will be obtained from the interest on the moneys left for this purpose out of the subscriptions collected in 1923 for the memorial to the late regretted Professor Eric GERARD. The prize will consist of a reproduction in enamel of his portrait in bas relief on the walls of the theatre of the Institute together with the sum of one thousand francs.

Each year the scientific Committee of the Association will advise the Committee administering the fund which paper it considers the best of those that have been read and published. At the end of each three-yearly period the Administrative Committee will name the winner of the prize out of the three candidates submitted in this way.

[ 385. (06.111 ]

# OFFICIAL INFORMATION

ISSUED BY THE

# PERMANENT COMMISSION

OF THE

## INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

### Meeting of the Permanent Commission held on the 17 July 1926.

The Permanent Commission of the International Railway Congress Association met on the 17 July 1926 at the Headquarters Office of the State Railways at Brussels, the President, Mr. Foulon, being in the chair.

* * *

Tributes were paid to the memory of Messrs. C. DE BURLET, J. KRUTTSCHNITT and D. PÉROUSE, former members of the Permanent Commission, and to that of Mr. Ed. HOLEMANS, secretary-treasurer of the Congress Association, who have died since the last meeting of the Commission.

* * *

I. — The meeting proceeded to nominate as members of the Permanent Commission Messrs. Cesare ODDONE, director-general of the Italian State Railways, and J. J. STIELTJES, inspector-general in the Inspection Department of the Netherlands Railways, and ratified the appointment of Mr. J. HABRAN, honorary administrative director of the Belgian State Railways and assistant secretary-treasurer of the Association, as secretary-treasurer in place of the late Mr. Ed. HOLEMANS.

* * *

II. — The balance sheet for the year 1925 which had been certified by an auditor, and the estimated budget for the year 1926, were approved.

The variable part of the annual subscription paid by participating administrations (article 17 of the statutes) has been fixed at 0.10 gold franc per kilometre for the current year 1926.

* * *

III. — At the closing meeting of the London Session the assembly decided, subject to the Spanish Government's approval, to hold the next Congress at Madrid in 1930.

The Belgian Government, through the usual diplomatic channels, has asked the Spanish Government if it approved, and has obtained the latter's assent.

The first steps in preparing a list of questions to be discussed at the Congress have been taken : a circular was sent out early in July 1926 to the members of the Permanent Commission as well as to the adherent organisations and the participating administrations.

* * *

IV. — The application of Bulgaria for membership in the Association was favourably received by the members present at the meeting. The number, however, was smaller than that required by article 4 of the statutes, and the absent members are being asked to give their approval.

* * *

The Commissioners chosen by the London Congress to examine the Association's accounts for the period 1 January 1923 to the 31 December 1925 have made their report, which states that the accounts were checked with ease owing to the care with which they had been kept.

The following companies have been admitted to, or have retired from, the Association since the last meeting :

| | Km. | Miles. |
|---|---|---|
| *Admissions :* | | |
| Buenos Ayres & Pacific Railway | 4 268 | 2 652 |
| Östra Skånes | 181 | 112 |
| Società Trazione Elettrica Lombarda | 105 | 65 |
| The following three Companies : | | |
| Festiniog Railway . . . 21.28 km. (13 miles). | | |
| Welsh Highland (Light Railway) . . . 41.07 — (26 — ). | 75.02 | 47 |
| Hundred of Manhood and Selsey Tramway Company . . . 12.67 — (8 — ). | | |
| as forming part of the « Kent, Somerset, Shropshire & Welsh Light Railways Group », already a member of the Association. | | |
| *Resignations :* | | |
| Costa Rica Railway | 306 | 190 |
| Chemin de fer d'intérêt local d'Indre-et-Loire | 192 | 119 |
| Chemin de fer Salentine | 243 | 151 |
| In accordance with article 4 of the statutes, the following Railways having been taken over by the Belgian State Railways, cease to be members of the Association : | | |
| Chemin de fer de Braine-le-Comte à Gand | 65 | 40 |
| Chemin de fer d'Eecloo à Bruges | 28 | 17 |
| Chemin de fer de Tournai à Jurbise et de Landen à Hasselt | 46 | 29 |

As a result of the amalgamation of certain companies and of the sub-division of one railway into two separate companies, the Railway Congress Association at July 1926 consisted of 229 administrations with a total length of 516 530 km. (320 963 miles) of line.

*The General Secretary,*
P. Ghilain.

*The President,*
Edm. Foulon.

# NEW BOOKS AND PUBLICATIONS

[ 62. (01 ]

TIMOSHENKO (S.), Formerly Professor of Mechanics in Kiev and Petrograd Polytechnical Institutes, Research Engineer, Research Dept. Westinghouse Electric and Manufacturing Company, and LESSELLS (J. M.), B. Sc., A. M. I. Mech. E., Mechanical Engineer, Resarch Dept., Westinghouse Electric and Manufacturing Company. — **Applied Elasticity, 1st edition.** — One volume (9 $\times$ 6 inches) of 544 pages, with 391 figures and XCV tables in the text. — 1925, Westinghouse Technical Night School Press, East Pittsburgh, Pa.

The great attention which is being paid at the present time to scientific design has brought about a demand for an increased knowledge by draughtsmen and designers of the materials with which their work is to be carried out.

It is no longer sufficient that during his training the engineering student should acquire only a slight insight into the theoretical side of his profession, spending the major portion of his apprenticeship in gaining practical knowledge.

In years gone by, the engineer designed his machine or structure, either as an experiment to be re-designed if it failed, or with what would appear to us to be a ridiculously high factor of safety. In the first case the result of his work was uncertain, and in both too costly for modern conditions.

At the present time there is an ever increasing demand for efficiency in all professions, and that required from the engineer is almost greater than from any other. This demand has called for a new type of engineer whose technical qualifications have been proved by his having passed some recognised examination taken either before or during his practical training.

This idea of the practical and theoretical running side by side has been developed by Messrs. Timoshenko and Lessells in their book on Applied Elasticity.

The volume is divided into two distinct parts: theoretical and experimental. Part I, written by Mr. Timoshenko, deals with the mathematical analysis of the strength of materials, introducing new methods for calculating the distribution of stresses which have been found to give far more accurate results than those given in the majority of text books. These will be found of great value to the designer when dealing with machines in which sharp variations in cross section of bars, holes or notches cannot be avoided and where it is necessary to know the exact distribution of stresses at these points. The application of trigonometrical series for obtaining deflection curves is discussed, as is the Rayleigh-Ritz method for considering vibration problems.

The early chapters of the book constitute a short review, with examples, of the usual elementary theories, and these serve considerably to simplify the more advanced problems which follow.

Amongst the subjects discussed in this portion of the book are the method of applying the hydrodynamical and membrane analogies to problems concerning the torsion of shafts of non-circular cross section, the grapho-analytical method, combined with the principle of superposition for obtaining deflection curves.

Chapter IV deals with the theory of the bending of bars on an elastic foundation. This theory is particularly use-

ful to railway engineers, as it can be applied to such problems as the deflection of railway tracks.

A new approximate method for solving column problems is developed in chapter VII, whilst chapter VIII discusses the theory of twist in crank shafts. In chapter IX such problems as the collapse of cylindrical tubes due to external pressure and the deformation of circular rings, as for example piston rings, are dealt with.

The theory of the bending of plates and some new data on the buckling of plates under pressure and shear in their middle plane are given.

In the last chapter of this part, the important problems of dynamical stresses produced in moving machine parts by inertia and vibration are considered.

The second part of the book, written by Mr. Lessells, deals with the experimental analysis of the physical properties of the materials used for building the structures considered from a purely mathematical point of view in part I.

The development of test room plant has been very rapid during recent years, not only in the re-designing of old types of machines to give greater accuracy, but also in the introduction of new machines and methods to cope with the increased demand for knowledge.

Mr. Lessels has in this portion of the book collected together details of almost every known method for testing material, and has included numerous examples to show how the information required may be obtained from the figures given by the various machines described.

Chapter XII, the first chapter in this part, is devoted to definitions. The importance of the reduction in area value, the effect of temperature and the speed of testing are also discussed. The result of cold work and overstrain on materials, with results of tests made are considered in chapter XIII. Impact tests with both notched and unnotched bars are dealt with in chapter XIV, whilst in the next chapter the subject of hardness is reviewed. In this chapter the recently developed pendulum method of testing hardness is described.

Fatigue, a subject which is at present receiving a great amount of attention from metallurgists and engineers, is discussed at length in chapter XVI.

Chapter XVII is devoted to the theory of strengths, this subject being dealt with rather more fully than is usual in a text book.

The last chapter contains much numerical information on working stresses, arranged in such a way as to be of real practical value, and also describes methods of proportioning the limiting stress values in design.

It would appear from the numerous references given in the text that the authors have spared themselves no pains in their efforts to produce a book which will be of value both to the engineering student and designer.

F.

---

[ **624**. (01 ]

MENDIZABAL (D.), engineer. — **Estudio de una nueva instrucción para el cálculo de tramos metálicos (The preparation of new regulations for the calculation of metal bridges)**. — One volume (7 1/2 × 10 inches) of 327 pages with 15 separate plates. — 1925, Madrid, Sucesores de Rivadeneyra (S. A.) — Artes gráficas, 20, Paseo de San Vicente. — Price : 30 pesetas.

Mr. Domingo Mendizabal has set out in this book to formulate on the most rational bases, regulations to be observed in the preparation of plans for and the calculations of metal bridges. He has taken as starting point the most recent

experience of the latest European and American regulations, from which he has drawn conclusions as to what is most suitable to meet the Spanish requirements. The principal sources of informaion are :

| | | | |
|---|---|---|---|
| Spanish | regulations | of | 1902 |
| Italian | — | of | 1909 |
| American | — | of | 1910 |
| Swiss | — | of | 1913 |
| French | — | of | 1915 |
| Argentine | — | of | 1916 |
| Canadian | — | of | 1920 |
| Belgian | — | of | 1920 |
| Indian | — | of | 1921 |
| Chinese | — | of | 1922 |
| German | — | of | 1922 |

He has divided his work into the following sections :

1) Data on which the calculations are based. Forces acting;
2) Loads and stresses in the members;
3) Verification of stability;
4) Arrangement of the scheme;
5) Inspections and tests;
6) Miscellaneous.

Mr. Mendizabal's book contains much interesting information, and it is unfortunate that owing to its being written in Spanish few French and English readers can make use of it. Whilst it is not possible to review the book in detail, certain parts which deserve particular attention, and especially those concerning railway bridges, are mentioned below.

*Rolling loads.* — After comparing the great differences between the rolling loads allowed by different countries, Mr. Mendizabal considers a locomotive having eight wheels coupled with a leading pony truck, the total wheelbase being 10 m. (32 ft. 9 11/16 in.).

The distance between the centres of the truck wheels and the leading coupled wheels is taken as being 2 m. 50 (8 ft. 2 7/16 in.) and between the coupled wheels 1.50 m. (4 ft. 11 in.) and the weights on the axles as being :

| | |
|---|---|
| Truck . . . . . | 12 t. |
| Coupled wheels . . | 22 t. |
| Total. . . . . . . . | 100 t. |

that is to say, 10 t. per metre (3 English tons per foot).

Mr. Mendizabal has also given particulars of the weights of the tender and of the loaded wagons.

When calculating the girders of railway bridges a train of two locomotives and tenders coupled together, followed by an indefinite number of loaded wagons should be considered. The flooring can also be calculated on the basis of the forces resulting from three axles each carrying 26 t. spaced at 1.50 m. (4 ft. 11 in.) centres when this loading causes higher stresses than the standard train.

*Metre (3 ft. 3 3/8 in.) gauge lines.* — The standard train for use in these calculations should consist of two locomotives and tenders at the head of the train with the necessary number of loaded wagons behind them.

The principal dimensions of the locomotives are :

| | |
|---|---|
| Wheelbase . . . . . . . . . | 11 m. 50 (37 ft. 8 3/4 in.). |
| Number of axles . . . . . . . | 6 |
| *Distance between centres of wheels :* | |
| Between two leading pairs . . | 2 m. 00 (6 ft. 6 3/4 in). |
| Between coupled wheels . . . | 1 m. 50 (4 ft. 11 in.). |
| Between two trailing pairs . . | 2 m. 20 (7 ft. 2 5/8 in.) |
| Weights on axles : | |
| Leading. . . . . . . . . . . . | 8 t. |
| Coupled. . . . . . . . . . . . | 16 t. |
| Trailing. . . . . . . . . . . . | 12 t. |
| Average weight per metre over total wheelbase. . . . . . . | 7.3 t. (2.19 English tons per foot). |

*Braking and adhesion.* — The author

considers that 1/7 of the weight on the locomotive axles and 1/12 on the wagon axles which may be on the bridge represent the effect due to the above.

*Temperature variations.* — The variations in temperature on either side of the mean are taken at 30° C. (54° F.).

*Reactions due to nosing.* — The reaction due to nosing is considered as a live force acting at the leading end and having a value equal to 1/5 of the heaviest axle load. It should not be added to the centrifugal force when on curves.

*Dynamical and impact effects.* — The effects due to the speed of the trains on railway under bridges induce vertical and horizontal centrifugal forces, inertia forces in the driving gear, friction, shocks, and vibrations which may or may not synchronise.

Experimental tests have led to certain empirical formulæ, such as those of Pencoyd, Major Mount, Waddell and Rabut being used, but they are none of them entirely satisfactory.

The mathematical analysis of impact effect is most complicated and in practice no satisfactory formula has been evolved. It is therefore necessary to make use of the results obtained by experiment after they have been submitted to and satisfied a critical and scientific analysis.

The most interesting of the formulæ adopted in various official regulations are the following :

*America :*

$$I = S \frac{91.5}{L + 91.5}$$

I = Increase of load due to impact;
S = Static load;
L = Length of span of the element.

*France :*

Increase of the load on the middle axle for short spans.

*Canada :*

$$I = S \frac{30\,000}{30\,000 + L^2}$$

*Germany :*

Different formulæ for different types of flooring.

For bridges with cross girders and longitudinal stringers without ballast :

$$1.19 + \frac{21}{l + 46}$$

*Formula suggested by Mr. Mendizabal.* — For short spans the dynamic increase can be estimated to amount to as much as 150 %.

For spans of more than 200 m. (656 ft. 2 in.) the increase is practically negligible.

Between these limits the curve representing the variation may be taken as an ellipse.

The spans ($l$) should be plotted along the horizontal axis $ox$, and the impact (I) along the vertical axis $oy$, $a$ and $b$ being half the major and half the minor axes of the ellipse respectively.

When

$a = 250$ m. (820 ft. 2 1/2 in. $I = 0$;

When $l = 0$, $I = b = 140\,\%$ ;

$$I = b - \frac{b}{a}\sqrt{2\,al - l^2}$$

$$I\,\% = 140 - 0.56\sqrt{500\,l - l^2}$$

The law of variation represented by a curve in the form of an ellipse suggested by Mr. Mendizabal has the advantages of being both simple and neat.

*Parts under alternating stress.* — After reviewing the different foreign regulations, the author proposes to evaluate the working stresses in accordance with the following formula :

$$R_t = \left(R - 2.5\frac{A}{B}\right)$$

Where R = normal working stresses;

$R_1$ = working stress allowed;
A and B, the minimum and maximum stress in absolute values in the part.

*Secondary stresses.* — Mr. Mendizabal has also considered the secondary stresses in lattice girders, and has drawn attention to the practical work done by the American engineer, Mr. Waddell, on this question.

Everything should be done to design the girders in such a way as to eliminate or limit these secondary stresses.

When these stresses are calculated and added to the dead load, moving loads, and to the reactions due to nosing and centrifugal forces, the allowable working stress can be 33 % above the allowable working stress.

If they are added to the whole of the stresses, both horizontal and vertical, acting in the girder, the allowable working stress can be increased by 50 %.

After considering in turn all those elements relating to the forces acting, such as, the stresses in the parts, the working loads allowed, the quality of material used and the inspection and test thereof, the tests to be made on the bridges, and the maximum deflection allowable, etc., Mr. Mendizabal has drawn up regulations in accordance with which schemes for metal bridges for standard and metre gauge should be prepared.

The book furthermore contains in detail the proposed regulations for road bridges in addition to many tables of loads and bending moments suitable for the Spanish regulations which have been borrowed from foreign regulations.

Finally, it may be repeated that owing to its having been written in Spanish the book is less accessible than it would be otherwise to French and English readers, who would undoubtedly find in it much interesting information.

R. D.

[ 313 .385 (.3) ]

# CORRIGENDA

We reproduce hereafter a letter received from the Government of India, Railway Department :

GOVERNMENT OF INDIA, RAILWAY DEPARTMENT.

(RAILWAY BOARD.)

No. 538-St. Simla, the 2nd September 1926.

**Mileage of Indian Railways.**

*To the Editor,*

« *Bulletin of the International Railway Congress Association* »,

*Brussels.*

I am directed to state that the mileage open on 31st December 1922 and 1923 shown as 40 491.1 against British India under table III — *Asia* — on page 364 of volume VIII, No. 4, of the *Bulletin of the International Railway Congress Association* (English edition) for the month of April 1926 is incorrect. The correct open mileage of all railways in India on the 31st March of the last four years is as follows which, it is requested, may be adopted in future issues of the Bulletin :

| | |
|---|---|
| Year ending 31st March 1923. | 37 617.91 miles. |
| — — — 1924. | 38 038.52 — |
| — — — 1925. | 38 269.78 — |
| — — — 1926. | 38 579.48 — |

. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .

(S.) . . . . . .
*Secretary, Railway Board.*